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THE UNIVERSITY OF ALBERTA

RELIEF AND MICROCLIMATE AS RELATED TO SOIL PROPERTIES

by

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A THESIS

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ABSTRACT

This study was undertaken to determine the influence of relief and microclimate on soil properties. Seven sites were chosen at different positions on the north- and south-facing slopes of a moderately rolling till knob. Physical, chemical, and mineralogical analyses were conducted to characterize the soils at the different positions. The vegetation of the area was characterized and soil temperature and moisture were monitored at four depths. Redox potential and pH were measured to detect seasonal variations.

Thickness of horizons and particle size distribution indicated that more leaching occurred in the lower slope positions on the north-facing slope. Data for oxalate- and dithionite-extractable iron and aluminum, cation exchange capacity, and X-ray diffraction showed only minor differences among the seven pedons.

Soil temperature was higher on the south-facing slope than on the north-facing slope and air temperature was usually higher than soil temperature at the 10 cm depth.

Soil moisture regime varied with position in the landscape. The soil on the north-facing slope was generally more moist than the soil on the south-facing slope.

Redox potential varied seasonally and appeared to be related to the moisture content of the soil.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table		Page
AIIId	Daily Moisture Content (%) at Four Depths	97
AIIIe	Daily Moisture Content (%) at Four Depths	98
AIV	Moisture Content (%) at Permanent Wilting Point and Field Capacity.	99

LIST OF FIGURES

Figure		Page

LIST OF PLATES

I. INTRODUCTION

Climate, as a parameter for categorizing soil pedons, is considered at various levels of abstraction in the taxonomic classification scheme for Canadian soils. The nature of the microenvironment of a soil is important in understanding the genetic processes active in its formation. Soil moisture and soil temperature vary among horizons both diurnally and seasonally. Climatic features of the soil are not as readily discernible as are other properties of the soil. Soil temperature cannot be preserved in a plastic sample bag, therefore it is not readily recognized as an important soil characteristic.

The parameters of climate are utilized broadly in the Canadian Classification scheme and do not reflect local or microclimatic conditions. The U.S.D.A. (1964) reports that the mean annual soil temperature can be estimated by adding 2°F to the mean annual air temperature. They have devised methods for estimating mean summer temperature for a given depth. However, the data available are only useful to estimate the seasonal temperature of soils that are freely drained, cultivated or grass-seeded, and at relatively level sites. There is a need for more information on the temperature and moisture regimes of sloping land surfaces.

The purpose of this study was to investigate variations in soil characteristics, especially those reflecting soil moisture and temperature as they relate to soil depth, slope of the land surface, and time of the year.

II. LITERATURE REVIEW

THE SOIL FORMING PROCESS AND THE FACTORS OF SOIL FORMATION

The soil represents a dynamic system in which a series of changes take place constantly that relate to its composition, properties, and energy condition. The soil forming process is the combination of these changes. The course of the soil forming process, i.e. the properties and composition of a series of soils that succeed each other in the process of evolution, is determined by the factors of soil formation.

Dokuchaev (1889) established the five factors of parent material, topography, climate, living organisms, and time as being responsible for soil formation. Joffe (1949) divided the soil forming factors into active factors consisting of climate and vegetation, and passive factors consisting of parent material, topography, and age of land. The original concept of Dokuchaev was adhered to by many pedologists and led to many studies of single factors related to soil formation. However, Dokuchaev considered all factors of soil formation equally important, contending that although all were necessarily active in combination, their relative influence and the character of their manifestations could vary substantially. Several pedologists expressed their views on the relative importance of each of these factors. Glinka (1927) and Ellis and Shafer (1940) recognized climate as the most important factor in soil formation. Ramann (1928) felt that parent material and environment are of about equal importance. Zakharov (1946) treated topography as of lesser importance than the other four soil forming factors.

In spite of the development of the theory dealing with the factors of soil formation and the numerous valuable studies related to it, the theory did not fully explain or investigate the whole range of the relationship between soil and environment. The soil and the factors of soil formation do not exist independently or in isolation but in mutual contact and interaction (Rode, 1955).

More modern concepts of soil genesis modify the older theories and place emphasis upon the operation of various processes. The balance of processes in any combination is emphasized. It is also suggested that shifts in balance among combinations of processes are responsible for soil differences rather than the operation of markedly different genetic processes (Simonson, 1959).

Soil genesis is conceived as an aggregate of many individual physical, chemical, and biological processes. Simonson (1959) views soil genesis as consisting of the accumulation of parent materials and the differentiation of horizons in the profile. Horizon differentiation results from additions, removals, transfers, and transformations in the soil system. Nikiforoff (1961) states that the"soil serves as a sort of turnstile through which pass endless swarms of atoms of excited matter". Many substances that comprise the soil may be affected by each of the four basic kinds of changes. There may be additions, removals, transformations, or transfers of clay minerals, soluble salts, sesquioxides, carbonates, and/or organic matter. Individual reactions may be more or less localized, some occurring near the surface while others take place at various depths. For example, organic carbon is oxidized primarily in the surface portion of the soil while free carbonates usually precipitate at some depth (Simonson, 1959).

Not all changes or alterations are caused by chemical reactions

nor do all processes promote horizon differentiation. The cracking and churning of clays and water erosion at the surface alter the soil (Simonson, 1959). Nikiforoff (1959) likens soil horizons to organs in a living body, each of which performs a specific function. The continuous performance of specific functions gives each horizon its individual morphological and chemical character. The widespread operation of the same kinds of changes in horizon differentiation is consistent with the existence of soils as a continuum over the land surface. This explains the existence of local and regional differences among soils and is consistent with the sharing of some properties by all soils (Simonson, 1959).

Topography as a Factor of Soil Formation

Topography appears neither as a source of energy nor of matter for soil formation, but it influences their redistribution over the earth's surface. Parent material and vegetation provide the source of soil material. Organisms of the soil and the life activity of higher plants play an active part in all soil processes related to decomposition, synthesis, and migration of substances. Climatic conditions determine the thermal and moisture regimes of soils and have an effect on all processes controlling their direction as well as intensity. Conversely, the influence of relief is expressed mainly in the differentiation, at the earth's surface, of all the phenomena constituting soil formation, and of all agencies affecting such phenomena (Gerasimov, 1960).

Different forms of relief are determined by differences in the elevation of the earth's surface. Some modification of all climatic characteristics ensues with changes of elevation. Volobuev (1963) states that "as altitude increases, there is a decrease in the duration

of the active period of soil formation, because of shorter periods with active temperatures". Mountain relief exerts a particularly strong influence on the formation and distribution of soils. The redistribution of solar heat and atmospheric moisture is more conspicuous in this type of region than anywhere else. The effects of mountainous relief is manifest in a conspicuous unevenness of soil cover, which consists of a great number of diverse associations. A type of vertical soil and plant zonality may be found at intervals associated with a changing pattern of microclimatic conditions.

Surface slope acts to differentially distribute atmospheric agencies. One of the main factors in redistribution by relief is the influence of topographical features on surface runoff. Runoff increases with steepness of slope. Therefore there is always some deficit of atmospheric moisture along slopes while moisture is added to lower lying areas. However, soil permeability has a bearing on the relative amount of runoff. The two regularities in the redistribution of atmospheric moisture play a part in the development of dissimilar soils. Neustreuv (1930) attempted to explain the lack of solonetzic soils on the mountains of Central Asia as resulting from improved drainage conditions. Koehne and Niklas (1921) observed considerable differences in the size of weathered rock particles in soils derived from material of the same geological origin but on different slopes.

Many pedologists have studied the variations in soil formation as determined by local slope. Norton and Smith (1930) and Aandahl (1948) concluded that the Ah horizon was thinner as slope became steeper. They reasoned that the thickness of the humus horizon depended upon the degree of moistening. Another obvious effect of relief in soil genesis is the degree of leaching which occurs on slopes in relation to more level

terrain. Norton and Smith (1930) noted that with increases in degree of slope and subsequent increase in surface runoff the following occurred: the depth to the zone of accumulation decreased; the texture became coarser; and structure became less defined.

Topography also acts as a factor in the redistribution of light energy which in part is converted into thermal energy at the surface of the soil. Steepness and exposure of slope have an effect on the amount of solar radiation reaching the soil surface. In all latitudes of the Northern Hemisphere, northern slopes receive the least amount of radiation in all seasons (Volobuev, 1963). In the Northern Hemisphere western slopes receive about as much sunshine as the eastern slopes. They become warmer, however, because in the first half day interval when eastern slopes are insolated much of the thermal energy is lost through evaporation. During the latter half day interval, when the western slopes are insolated, evaporation decreases rapidly because of soil desiccation.

The variations in hydrothermic regime on slopes of different steepness and exposure are reflected in the character of the vegetation (Volobuev, 1963). Variations of climate and vegetation on different slopes can cause wide variation in soil development depending on the slope gradient. Volobuev (1963) generalizes that soils of southern slope exposure are usually less developed and often more calcareous. He further states that soils of the northern slopes are usually better developed and have thicker sola. The differences in microclimate and associated differences in vegetation are probably the major factors contributing to the genetic differences of these soils.

Topographic shape also has an effect on soil genesis. Voeikov, as reported by Shul'gin (1957) showed that as a general rule daylight

warming and night cooling are strongest on concave surfaces and least on convex surfaces. This reflects the intensity of air mixing.

Acton (1965) observed a close relationship between a soil member within an association and the nature of the slope segment on which it occurred. Calcareous Dark Brown soils were noted on the uppermost convex portion of the slope on gradients usually greater than 8 percent; Orthic Dark Brown soils on simple intermediate slopes of 5 to 8 percent; Eluviated Dark Brown soils on slightly concave footslopes of 1 to 3 percent gradient. Furthermore, he observed Rego Dark Brown soils wherever 3 to 5 percent slopes extended from the margin of depressions and Gleysolic soils occupied the concave depressions. The extent of the different soil members was a function of the individual slope segment present in the landform.

While the most general regularities of soil geography depend in principle on major variations in the hydrothermal environment related to global climatic zones, the geomorphological factor must not be disregarded in studying soil distribution. The influence of relief is expressed mainly in the far reaching differentiation at the earth's surface of all the phenomena constituting soil formation and of all agencies affecting such phenomena.

Climate as a Factor of Soil Formation

Climate is a source of matter and energy for soil formation and acts directly upon soil development. The moisture and temperature (hydrothermic) regime influences the rates of decay and leaching of organic residues, the rate of weathering of minerals and the physical state of the soil through freezing, desiccation, and other processes.

Climatic factors affect additions, removals, transfers and

transformations in the soil. Within limits, as precipitation increases and temperatures fall, the organic matter content of soils increases. Jenny (1941) states that at a constant temperature, soil nitrogen increases logarithmically with increasing moisture. This fact is illustrated when the Black soils are compared to the Brown soils of Alberta.

The realization of the climatic element in soil formation led many pedologists to group soils according to climatic characteristics. Zonal soils are characterized by well-differentiated horizons and by profiles that differ markedly according to the climatic-ecological zone within which they occur (Muchenhirn et al, 1949).

Continental soils strongly reflect variation in regional climate. In general, Chernozemic soils occur under similar climatic conditions in Canada and in the USSR. Local climate or microclimate provides a soil environment differing from that of the general climate and produces soils with characteristics different from those of the region as a whole. In areas of rolling or hilly topography, there is usually an accumulation of stagnant cold air descending from the higher terrain. Frost-free periods may be lower in valleys than on the tops of ridges. The greater cooling of depressions is significant in the formation of soils. A slope exposed to the sun and wind from the south will be warmer and drier than one facing north and east in the Northern Hemisphere.

1. Relationships Between Soil Properties and Temperature Regime

Soil temperature is a parameter important to both soil genesis and soil use. It reflects the thermal energy of the soil system at any given time which in turn affects the rate of various physical and chemical reactions within the soil pedon. The significance of temperat-

ure is emphasized by van't Hoff's temperature rule (quoted by Jenny, 1941) which can be stated as follows: "For every 10 °C rise in temperature the velocity of a chemical reaction increases by a factor of two to three".

The oscillation of soil temperature also brings about the physical decomposition of mineral matter. The variation in temperature plays a major role in physical weathering. In tropical regions, weathering occurs three times faster than in temperate zones and nine times more rapidly than in the Arctic (Jenny, 1941).

Ramann (1911) noted the importance of the degree of dissociation of water in the hydrolytic decomposition of silicates. He observed that chemical reactions in the soil almost cease at temperatures below freezing which suggests that only temperatures above freezing should be considered in pedogenic processes. Other workers have disagreed, claiming that the freezing temperature of soils is lower than that of water. However, the freezing and thawing of soils has a favourable influence on the formation of soil structure and on the migration of soil fauna into the lower layers which improves the looseness and water-permeability of the soil (Rode, 1955).

Biological processes are also affected by the temperature conditions of the soil. Thus the rate of decomposition of organic residues is related to soil temperature. In warm climates, the decomposition of vegetative matter is accelerated while in cool regions accumulation is favoured.

Seasonal soil temperatures are affected by vegetative cover, slope direction and steepness, snow, groundwater, rain, and clouds. Data on the relationship of soil temperature to slope gradient and direction are scarce. Cantlon (1953) and Franzmeier _et al_. (1969)

measured soil temperatures under deciduous cover on the north- and south-facing aspects of slopes having a gradient of about 35 percent. Both studies showed that the north-facing slopes were about 2°C cooler in the upper 10 cm of the profile. In California data was reported by the Soil Conservation Service (U.S.D.A., 1964) for soil temperatures under grass on north- and south-facing slopes of 20 to 30 percent. It was found that the south-facing slopes were 6.4°F warmer than the north-facing slopes over a period of one year.

MacHattie and McCormack (1961) reported microclimatic observations on a ridge cleared of forest cover and on a similar ridge having forest cover. Soil temperature data gathered at the 10 cm depth showed that the south slope is always warmer than the north slope. The temperature was also found to increase progressively from May to September. Differences due to aspect were less on a wooded ridge than on a cleared ridge. Maximum temperatures were about 7°F lower on the north slope of the wooded ridge than at a corresponding location on the cleared ridge. These observed differences in temperature which result from aspect play a role in the differentiation of structure, color, and organic matter content of soils.

Several authors (Bouyoucos, Chang, Bowser and Leat) studied the effect of the surface horizon on the soil temperature regime. The nature of the surface of the soil determines the amount of solar energy which is absorbed, emitted or reflected. Bouyoucos (1916) reported that there was actually no difference in the mean annual soil temperature at the 6 inch depth between drained peat and medium to fine textured mineral soils in Michigan. Chang (1958) showed that the mean annual temperature of a wet bog and a well-drained sand are nearly the same. From soil temperature measurements at the 10 cm depth, Bowser and Leat (1958)

concluded that soil temperature in a cultivated field was consistently higher than soil under native vegetation. Weekly recordings at the cultivated plot averaged 16.3°C for the growing season as compared to 10.5°C at the plot with native vegetation.

At any given time, soil temperature varies from horizon to horizon. It fluctuates also with the time of day and with the season, the magnitudes of the fluctuations depending to a large extent on the exchange of energy between the soil and the environment. Therefore, various processes operating on the soil will vary in rate with depth. Chang (1958 a), at Griffith, Australia, showed that between 6 AM and 12 noon, the surface temperature of soils rises but the temperature at 24 cm falls. He noted that the daily maximum at the surface occurred at about 3 PM, but the maximum at 24 cm is not reached until between 8 PM and 10 PM. Rode (1955, after Homen 1897) showed that the temperature at the 10 cm depth fluctuated between about 14°C and 21.5°C on an August day in Finland. At the 50 cm depth, the fluctuation was only a fraction of one degree and at 50 to 70 cm no fluctuation occurred.

2. The Relationships Between Soil Properties and the Moisture Regime

The moisture regime of a soil has both a direct and indirect influence on pedogenesis. The morphological, chemical, and physical features of the soil profile are related to the movement of moisture which transfers substances from one place in the soil body to another. The qualitative and quantitative distribution of substances through the soil profile is controlled by the volume of available percolating waters (Joffe, 1949).

Moisture added to the soil surface as well as that added through groundwater discharge act in additions, removals, transfers, and

transformations in the soil. The nature and amount of organic matter in each horizon of a soil is partly determined by the moisture regime. The nitrogen and organic matter content of surface soils become higher as moisture increases when other soil-forming factors are constant. Plant life is more abundant in humid climatic regions than in more arid regions.

Transfers within and losses from the soil pedon are due mainly to leaching or eluviation. Before leaching can occur, water must move through a soil. Minerals and organic materials, either in solution or suspension are transported by water either downward or laterally. In general, leaching affects soils of humid regions more than it does soils of arid regions. With greater rainfall more water is available for percolation through the soil. Soluble salts, carbonates, calcium, sodium, and potassium are slowly leached from the sola of well-drained soils in humid regions (Simonson, 1957). Leaching also contributes to horizon differentiation in well-drained soils of dry regions but in these regions soluble salts and carbonates are not usually as far down in the profile.

In soils without free drainage, soluble salts and carbonates may accumulate wherever the water table occurs, even close to or at the soil surface. Therefore, the position in the landscape will affect the drainage of soils and result in varying profile development. McKeague (1965) measured the seasonal changes in water table and redox potentials of three clay soils in different slope positions and related his findings to the morphological, physical, chemical, and mineralogical properties of these soils. He noted that at the site where the water table remained several feet below the surface and where oxidizing conditions prevailed, the soil development involved the depletion of bases from the solum and the differentiation of an Ah horizon overlying a Bm horizon. At the site where the water table remained at or near the

surface, where the soil below a depth of a few inches was always wet, and where reducing conditions prevailed during much of the year at depths below 2 feet, the only marked horizon development was the accumulation of a muck layer at the surface. The soil which was subject to the widest fluctuations in water table depth, in wetness and dryness, and in oxidation-reduction status was found to be the most strongly developed.

III. MATERIALS AND METHODS

STUDY AREA

The study, initiated in the fall of 1969 and terminated in October of 1971, was undertaken in an area approximately 30 miles west of Edmonton in Township 53, Range 3, west of the 5th meridian (Figure 1). The research sites were established in an area of hummocky disintegration moraine and located on an isolated knoll comprised of relatively uniform glacial till. Seven sites were chosen on a relatively uniform slope with a dominantly aspen tree cover. One site was chosen on the crown of the slope with mid to upper slope, lower slope, and depressional sites located on both the north- and south-facing aspects (Figure 2).

SAMPLING AND INSTALLATION OF APPARATUS

Sampling at each site was carried out during the fall of 1969 and the summer of 1970. During the course of sampling, moisture-temperature cells described by Colman (1949) were installed at each site. The cells, approximately 2.5 cm by 4 cm by 0.3 cm thick, consist of two plates separated by a fiberglass binding which provides a coupling that varies with the moisture content of the surrounding medium. A small thermistor for temperature measurement completes this two circuit, three-wire unit.

The cells were installed at the 10 cm depth (Ah or Ae horizon), the 30 cm depth (Bt horizon), the 50 cm depth (BC horizon), and the 100 cm depth (Ck horizon) below the soil surface. The cells

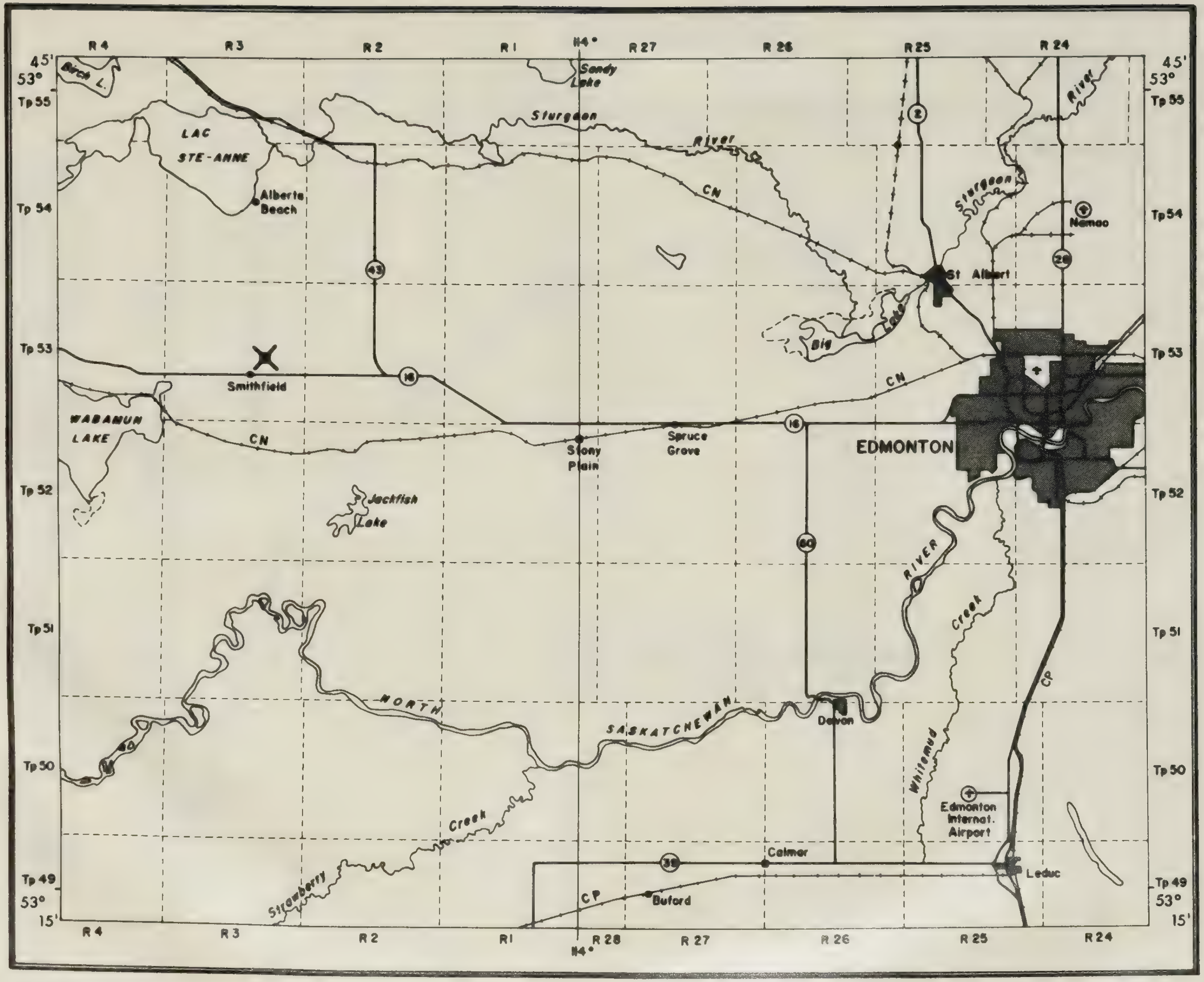


FIGURE 1 — Location of Study Area (✖)

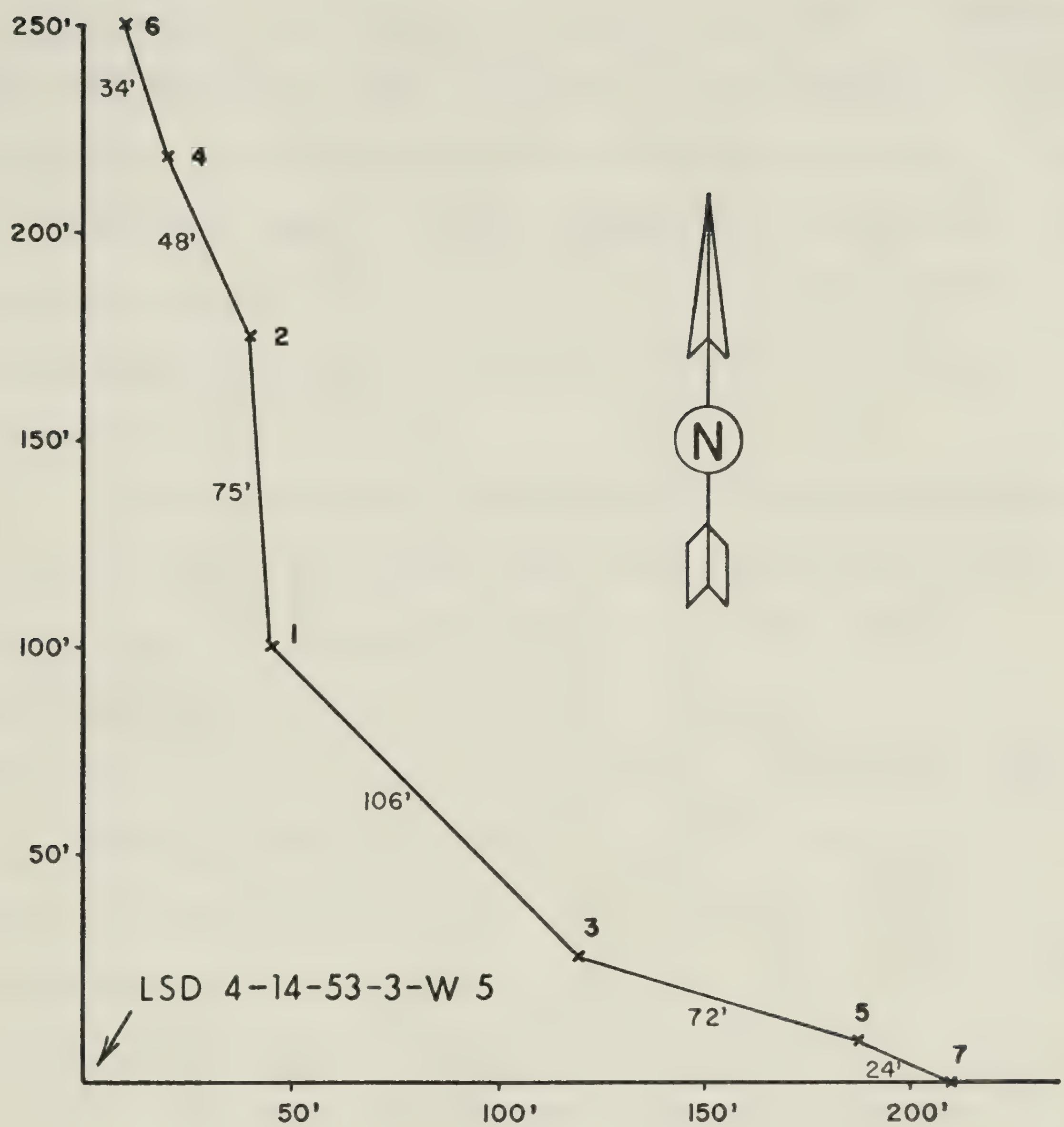


FIGURE 2—Plan View of Sites in the Study Area

were installed according to a modification of the methods used by van Groenewoud and Weegar (1968). For the 10 cm depth, a core of soil was removed and the cell inserted into the side of the hole. The core was then replaced. To position cells at the other three depths, the top 30 cm of soil were removed with a hand core, while the remaining depths were obtained by using an auger of 5 cm in diameter. Soil was packed around the cells and the cells dropped into the holes. Then the soil, previously removed by coring and augering, was replaced. In order to make measurements, the wire leads of the cells were connected to a Soiltest MC-300A soil Moisture Meter which measures current in microamperes.

The soil cells were calibrated for temperature measurement before installation and checked again after removal from the sites. Standard curves were prepared to convert instrument readings to degrees Centigrade. The soil cells were calibrated for moisture measurement by a field method. This involved repeated soil sampling in the immediate vicinity of each soil cell. The samples were oven-dried to determine moisture content and a standard curve was prepared. Temperature measurements were quite reliable; however, some problems were encountered with moisture measurements. Differences were difficult to detect when the moisture content dropped below the wilting point and when the soils were fully saturated.

Measurements were usually made twice weekly, Monday at about 9 to 10 AM and Friday at 3 to 5 PM. Morning readings far outnumbered the afternoon readings especially during the months of May, September, and October when all readings were made in the morning. In addition, pH and redox potential were measured at least once monthly. These

measurements were obtained with a Beckman Electromate pH Meter using a combination electrode for pH and a platinum electrode for redox measurements. The pH determinations were made on a horizon basis. For redox measurements, the platinum electrode was inserted into a hole dug into the side of the soil pit at the 10, 30, 50, and 100 cm depths. Beginning in May of 1970, rainfall was measured at each site and a control gauge was located in a clearing nearby.

METHODS

1. Preparation of Samples

The soils at each site were sampled on a horizon basis. These samples were air-dried at room temperature in the laboratory and then ground to pass through a 2 mm sieve.

2. Physical Analyses

(a) Mechanical Analysis: Mechanical analysis of the soil samples was determined by the pipette method of Toogood and Peters (1953). Organic matter was removed with H_2O_2, and calcium carbonate was removed with 0.1 N HCl. The oven-dried total sand fraction was placed on a nest of sieves of appropriate sizes to separate the sand sizes. The sieves were shaken for 30 minutes. The percentages of sand, silt, and clay fractions are based on oven-dry weight of organic matter-free, salt-free, and carbonate-free soil material.

(b) Field Capacity: The pressure plate method as described in the U.S.D.A. Handbook 60 was used to determine the field capacity of the soils. A pressure of 0.33 bar was used throughout the determinations.

(c) Permanent Wilting Point: The pressure membrane apparatus as described in the U.S.D.A. Handbook 60 was used to determine the permanent wilting percentage at 15 bars pressure.

3. Chemical Analyses

(a) Total Carbon: Total carbon was determined with the Leco Model 577-100 carbon analyzer. A representative sample for this analysis was ground to pass a 35 mesh sieve.

(b) Total Nitrogen: Total nitrogen was determined by the Kjeldahl method of Jackson (1958).

(c) Calcium Carbonate Equivalent: Calcium carbonate equivalent was determined by the calcimeter method of Bascomb (1961) using the apparatus described by Smolik (1953).

(d) Extractable Iron and Aluminum: The citrate-dithionite extraction method outlined by Jackson (1956), and the oxalate-extractable method of McKeague and Day (1966) were used for removal of iron and aluminum oxides. Iron content was determined by a Perkin Elmer Model 303 Atomic Absorption Spectrophotometer. Aluminum was determined colorimetrically using aluminon.

(e) Cation Exchange Capacity: Exchangeable cations were extracted from the samples with 1 N NH_4OAc adjusted to pH 7 (A.O.A.C. Methods of Analysis, 1955). The cation exchange capacity was determined by extraction of adsorbed ammonium with 1N NaCl and distillation of the extract was carried out according to the method outlined in A.O.A.C. (1955).

(f) Exchange Acidity: Exchange acidity was measured by leaching with 0.5 N BaOAc (pH 7).

4. Clay Analysis

(a) Preparation of Clay Samples: The total clay fraction was separated from the samples by gravity sedimentation as outlined by Jackson (1949) and modified by Pawluk (1961). Carbonates, soluble salts, and organic matter were first removed from the sample. The clays were dispersed by adjusting the soil suspension to pH 8 with NaOH. The clays were separated by repeated decantation of the upper 8 cm of suspension after standing for six hours and eight minutes, as calculated from Stokes' Law (Baver, 1956). The clay fraction was flocculated with $MgCl_2$ and KCl singly, followed by washing with distilled water and ethanol to remove chlorides.

(b) X-ray Analysis of Clay Minerals: The slides for X-ray analysis were prepared according to the method of Kittrick (1961). A few drops of clay suspension were placed on a glass slide and allowed to dry. Glycolation was achieved by placing the prepared slides in a saturated atmosphere of ethylene glycol at 60° C for 48 hours. Dehydration was accomplished by heating the slides to 550° C for two hours.

The clays were identified with a Philips X-ray Diffractometer equipped with a high angle goniometer, CuKα radiation, and a nickel filter. The X-ray unit was set at 40 kilovolts, 20 milliamperes with a scanning time of one degree 2θ per minute. Slit sizes used were 1°, 0.1 mm, and 1° with a chart speed of 1 cm per minute.

IV. DESCRIPTION OF THE SOILS AND VEGETATION IN THE STUDY AREA

The soils of the study area have developed on till derived mainly from the Edmonton Formation (Lindsay et al., 1968). These soils are classified in the Luvisolic and Gleysolic Orders of the Canadian System of Soil Classification (1970). Descriptions of the soils at each site are presented in Tables 1 to 7. Photographs of some of the soil profiles are presented in Plates 1 and 2. A cross-section of the study area is illustrated in Figure 3.

The vegetation at the seven sites is not widely variable, but there is a difference in the extent of occurrence of the various species. Aspen poplar (*Populus tremuloides*) is the common tree species at sites 1, 2, and 3 while paper birch (*Betula papyrifera*) and balsam poplar (*Populus balsamifera*) are of secondary importance. At sites 4, 5, 6, and 7 balsam is the dominant species with birch occurring to a significant extent. Aspen is of secondary importance at these sites. Birch occurs throughout the area but is most common in the poorly drained positions. Alder (*Alnus crispa*) and willow (*Salix* spp.) are most abundant at the depression and lower slope sites. One of the most noticeable differences in vegetative cover between the two aspects is the significant amount of mosses on the north-facing slope in comparison to the south-facing slope. Moss species are most common at sites 4, 6, and 7. The Saskatoon berry (*Amelanchier alnifolia*) occurs in the upper portions of the south-facing slope but does not occur on the north-facing slope. The vegetation at some of the sites is presented in Plates 3 and 4. The species common to the study area and individual sites are presented in Table 8.

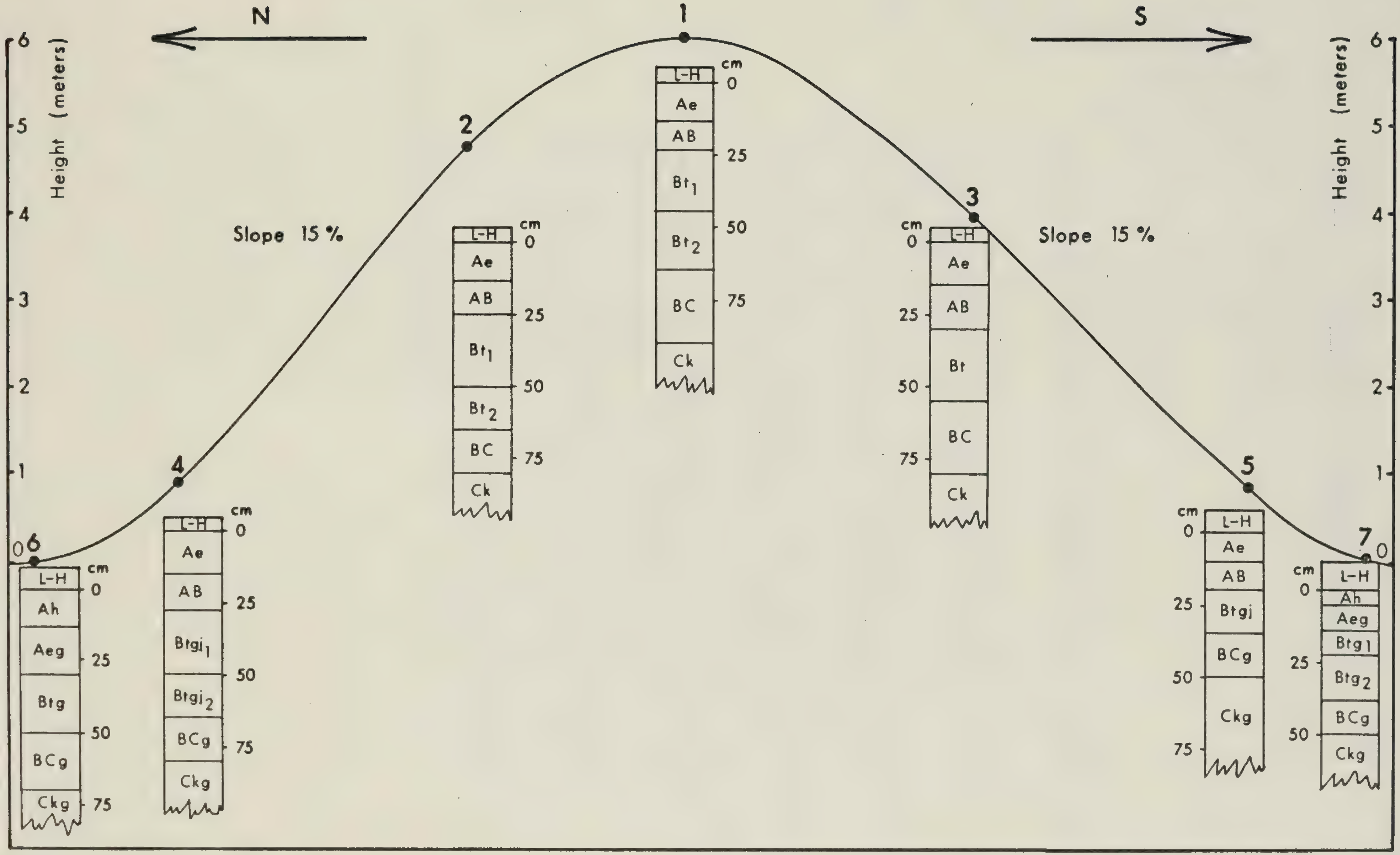


FIGURE 3 — Cross-Section of the Study Area

TABLE 1 - Description of Profile at Site 1

Classification: Orthic Gray Luvisol

Position: Crown

Drainage: Moderately well drained

L-H	5 to 0 cm, deciduous leaf litter and grasses, partially decomposed in lower portions; abundant, coarse, medium, and fine roots.
Ae	0 to 13 cm, light brownish gray (10YR 6/2, m*); strong, fine platy; friable; plentiful, very fine and fine roots; abrupt, smooth boundary; 10 to 18 cm thick.
AB	13 to 23 cm, yellowish brown (10YR 5/4, m) loam; moderate, fine subangular blocky; friable; few, very fine and fine roots; clear, wavy boundary; 5 to 15 cm thick.
Bt_1	23 to 45 cm; brown (10YR 4/3, m) clay loam; strong, medium blocky; firm; few, very fine roots; many, moderately thick clay skins; wavy boundary; 20 to 35 cm thick.
Bt_2	45 to 63 cm, brown (10YR 4/3, m) clay loam; weak, prismatic breaking to strong, medium blocky; firm to very firm; very few, very fine roots; many, moderately thick clay skins; abrupt, wavy boundary; 10 to 30 cm thick.
BC	63 to 95 cm, dark grayish brown (2.5Y 4/2, m) clay loam, weak, fine subangular blocky; firm; abrupt, irregular boundary; 25 to 45 cm thick.
Ck	at 95 cm, olive brown (2.5Y 4/4, m) silt loam to loam; amorphous; firm; slightly stony till; weakly calcareous.

* moist Munsell color designation

TABLE 2 - Description of Profile at Site 2

Classification: Orthic Gray Luvisol

Position: Mid to upper slope

Aspect: North-facing

Drainage: Moderately well drained

L-H	5 to 0 cm, deciduous leaf litter and grasses, partially decomposed in lower portion; abundant,coarse, medium and fine roots.
Ae	0 to 13 cm, light brownish gray (10YR 6/2, m) sandy loam; strong, fine platy; friable; few, fine and medium roots; abrupt, smooth boundary; 8 to 15 cm thick.
AB	13 to 25 cm, yellowish brown (10YR 5/4, m) loam; moderate to weak, fine subangular blocky; firm; few, very fine roots; clear, wavy boundary; 8 to 18 cm thick.
Bt_1	25 to 48 cm, brown (10YR 4/3, m) clay loam; moderate, prismatic breaking to strong, large blocky; very firm; very few, fine roots; many, moderately thick clay skins; clear, wavy boundary; 18 to 30 cm thick.
Bt_2	48 to 65 cm, brown (10YR 4/3, m) clay loam; weak, prismatic breaking to strong, medium blocky; very firm; many, moderately thick clay skins; clear, wavy boundary; 13 to 25 cm thick.
BC	65 to 83 cm, dark grayish brown (2.5Y 4/2, m) clay loam; moderate, medium subangular blocky; firm; clear, wavy boundary; 13 to 30 cm thick.
Ck	at 83 cm, olive brown (2.5Y 4/4, m) sandy clay loam; amorphous; friable; slightly stony till; weakly calcareous.

TABLE 3 - Description of Profile at Site 3

Classification: Orthic Gray Luvisol

Position: Mid to upper slope

Aspect: South-facing

Drainage: Moderately well drained

L-H	5 to 0 cm, deciduous leaf litter and grasses, partially decomposed in lower portion; plentiful, coarse, medium, and fine roots.
Ae	0 to 15 cm, pale brown (10YR 6/3, m) sandy loam; plentiful, very fine and fine roots; moderate to strong, fine platy; friable; abrupt, smooth boundary; 8 to 20 cm thick.
AB	15 to 30 cm, yellowish brown (10YR 5/4, m) loam; moderate, fine subangular blocky; firm; plentiful, very fine and fine roots; clear, wavy boundary; 10 to 18 cm thick.
Bt	30 to 55 cm, dark yellowish brown (10YR 4/4, m) clay loam; moderate, medium prismatic breaking to moderate, medium blocky; very firm; few, fine roots; many, moderately thick clay skins; clear, wavy boundary; 20 to 40 cm thick.
BC	55 to 80 cm, dark grayish brown (2.5Y 4/2, m) loam; moderate, fine subangular blocky; firm to very firm; very few, very fine roots; clear, wavy boundary; 18 to 38 cm thick.
Ck	at 80 cm, olive brown (2.5Y 4/4,m) loam; amorphous; friable; slightly stony till; weakly calcareous.

TABLE 4 - Description of Profile at Site 4

Classification: Gleyed Gray Luvisol

Position: Lower slope

Aspect: North-facing

Drainage: Imperfectly drained

L-H	5 to 0 cm, deciduous leaf litter and grasses, partially decomposed in lower portion.
Ae	0 to 15 cm, grayish brown (10YR 5/2, m) silt loam; strong, fine platy; friable; plentiful, fine roots; abrupt, smooth boundary; 10 to 23 cm thick.
AB	15 to 27 cm, grayish brown (2.5Y 5/2, m) loam; moderate, fine subangular blocky; firm; few, very fine roots; wavy boundary; 10 to 23 cm thick.
$Btgj_1$	27 to 50 cm, dark grayish brown (2.5Y 4/2, m) clay loam; few, fine, distinct reddish brown (5YR 5/6, m) mottles; moderate prismatic breaking to strong, coarse blocky; very firm; few, fine roots; many, moderately thick clay skins; wavy boundary; 15 to 35 cm thick.
$Btgj_2$	50 to 65 cm, olive brown (2.5Y 4/4, m) clay loam; few, fine, distinct reddish brown (5YR 5/6, m) mottles; weak prismatic breaking to strong, medium blocky; very firm; very few, very fine roots; common, moderately thick clay skins; clear, irregular boundary; 13 to 25 cm thick.
BCg	65 to 80 cm, olive brown (2.5Y 4/4, m) clay loam; common, fine, distinct reddish brown (5YR 5/6, m) mottles; moderate, medium subangular blocky; very firm; clear, wavy boundary; 15 to 30 cm thick.
Ckg	at 80 cm, olive brown (2.5Y 4/4, m) loam to clay loam; common, fine, distinct reddish brown (5YR 5/6, m) mottles; firm; slightly stony till; weakly calcareous.

TABLE 5 - Description of Profile at Site 5

Classification: Gleyed Gray Luvisol

Position: Lower slope

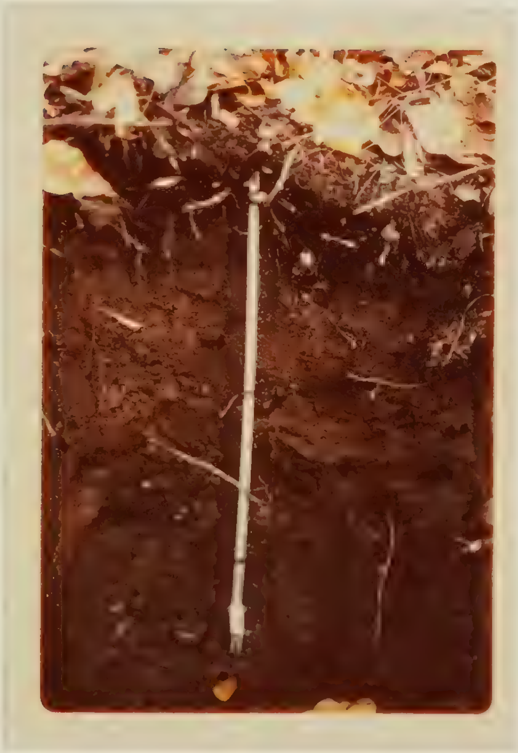
Aspect: South-facing

Drainage: Imperfectly drained

L-H	8 to 0 cm, deciduous leaf litter and grasses, partially decomposed in lower portions.
Ae	0 to 10 cm, yellowish brown (10YR 5/4, m) loam; moderate, fine platy; friable; few, fine roots; clear, wavy boundary; 8 to 20 cm thick.
AB	10 to 20 cm, dark grayish brown (10YR 4/2, m) loam, weak, fine subangular blocky; firm; few, fine roots; clear, wavy boundary; 5 to 15 cm thick.
Btgj	20 to 33 cm, dark yellowish brown (10YR 4/4, m) clay loam; common, fine, faint, yellowish brown (10YR 5/6, m) mottles; moderate, fine subangular blocky; firm; few, very fine roots; common, thin clay skins; clear, irregular boundary; 10 to 20 cm thick.
BCg	33 to 43 cm, dark grayish brown (2.5Y 4/2, m) clay loam; many, fine, distinct, yellowish brown (10YR 5/6, m) mottles; moderate, fine subangular blocky; firm; clear, wavy boundary; 8 to 20 cm thick.
Ckg	at 43 cm, olive brown (2.5Y 4/4, m) clay loam; many, fine, prominent yellowish brown (10YR 5/6, m) mottles; amorphous; firm; slightly stony till; moderately calcareous.

Profile at Site 2

Profile at Site 4



Profile at Site 5

PLATE 1 - Soil Profiles at Sites 2, 4, and 5

TABLE 6 - Description of Profile at Site 6

Classification: Orthic Humic Eluviated Gleysol

Position: Depression

Aspect: North-facing

Drainage: Poorly drained

L-H	8 to 0 cm, decomposed deciduous leaf litter and grasses.
Ah	0 to 13 cm, very dark grayish brown (10YR 3/2, m) loam; moderate, medium granular ("shot-like"); friable; abundant, very fine and fine roots; clear, irregular boundary; 8 to 18 cm thick.
Aeg	13 to 30 cm, brown (10YR 5/3, m) sandy loam; many, fine, distinct (10YR 6/6, m) mottles; weak, fine platy; friable; few, very fine roots; clear, wavy boundary; 13 to 25 cm thick.
Btg	30 to 50 cm, dark grayish brown (10YR 4/2, m) clay loam; many medium, distinct strong brown (7.5YR 5/6, m) mottles; moderate, medium granular; very firm; common, moderately thick clay skins; clear, wavy boundary; 18 to 38 cm thick.
BCg	50 to 68 cm, gray (5Y 5/1, m) clay loam; many, medium, distinct, strong brown (7.5YR 5/6, m) mottles; moderate, medium granular; very firm; clear, wavy boundary; 13 to 20 cm thick.
Ckg	at 68 cm, olive brown (2.5Y 4/4, m) clay loam; many, medium, distinct yellowish red (5YR 4/6, m) mottles; amorphous; firm; slightly stony till; weakly calcareous.

TABLE 7 - Description of Profile at Site 7

Classification: Low Humic Eluviated Gleysol

Position: Depression

Aspect: South-facing

Drainage: Poorly drained

L-H	15 to 0 cm, decomposed deciduous leaf litter and grasses.
Ah	0 to 5 cm, very dark grayish brown (10YR 3/2, m) loam; moderate, medium granular; friable; abundant, fine and very fine roots; clear, wavy boundary; 0 to 10 cm thick.
Aeg	5 to 13 cm, gray (10YR 5/1, m) sandy loam; many, fine distinct (10YR 5/6, m) mottles; weak, fine platy; friable; few, very fine roots; clear, wavy boundary; 5 to 10 cm thick.
Btg_1	13 to 18 cm, gray (10YR 5/1, m) loam; many, medium, distinct strong brown (7.5YR 5/6, m) mottles; weak, fine subangular blocky; firm; very few, very fine roots; few, thin clay skins; clear, wavy boundary; 5 to 14 cm thick.
Btg_2	18 to 38 cm, gray (10YR 5/1, m) loam to clay loam; many, medium, prominent yellowish red (5YR 4/8, m) mottles; weak, fine subangular blocky; firm; very few, very fine roots; few, thin clay skins; clear, irregular boundary; 13 to 30 cm thick.
BCg	38 to 50 cm, gray (10YR 5/1, m) clay loam; many, medium prominent yellowish red (5YR 4/8, m) mottles; moderate, medium granular; firm; clear, wavy boundary; 8 to 25 cm thick.
Ckg	at 50 cm, olive brown (2.5Y 4/4, m) clay loam; many, large prominent yellowish red (5YR 4/8, m) mottles; amorphous; firm; slightly stony till; weakly to moderately calcareous.

Profile at Site 6

Profile at Site 7

PLATE 2 - Soil Profiles at Sites 6 and 7

TABLE 8 - Vegetation Species of the Study Area

Scientific Name	Common Name	Site Location
Trees:		
Betula papyrifera	Paper Birch	1,2,3,4,5,6,7
Populus balsamifera	Balsam Poplar	2, 4,5,6,7
Populus tremuloides	Aspen Poplar	1,2,3,4,5
Shrubs:		
Alnus crispa	Alder	2, 4,5,6,7
Amelanchier alnifolia	Saskatoon	1, 3
Cornus stolonifera	Red Osier Dogwood	4,5,6,7
Rosa acicularis	Wild Rose	1,2,3, 5,6,7
Rubus pubescens	Dew Berry	4,5,6
Salix spp.	Willow	2, 4,5,6,7
Viburnum edule	Low Bush Cranberry	1,2, 5
Halfshrubs:		
Cornus canadensis	Bunchberry	1,2,3,4,5,6,7
Linnaea borealis	Twin Flower	1,2,3,4,5,6
Herbs:		
Achillea millefolium	Yarrow	5,6,7
Aralia nudicaulis	Wild Sarsaparilla	1,2,3,4,5, 7
Epilobium angustifolium	Fire Weed	2, 4,5,6,7
Fragaria virginiana	Strawberry	1, 3, 5
Galeum boreale	Northern Bedstraw	1,2
Lathyrus ochroleucus	Pea Vine	1,2,3
Petasites palmatus	Colt's foot	2,3,4,5
Pyrola asarifolia	Common Pink Wintergreen	1,2, 4,5,6
Vicia americana	Vetch	6,7
Mosses:		
Hylocomium splendens	Feather moss	4, 6,7
Mnium		2, 4, 6,7
Ptilium spp.	Plume moss	6,7

Autumn Scene on the North-Facing Slope

Vegetation at Site 4

Ground Cover at Site 6

PLATE 3 - Vegetation on the North-Facing Slope

Vegetation at Site 1

Vegetation on the Lower South-Facing Slope

PLATE 4 - Vegetation at the Crown and Lower South-Facing Slope

V. RESULTS AND DISCUSSION

For discussion purposes the results obtained are presented in two parts. Part A deals with results obtained from laboratory analyses to determine whether any variation exists among the pedons at the seven sites. Part B deals with data obtained from the measurement of soil reaction (pH), soil temperature, soil moisture, and redox potential in the field.

Part A - Discussion of Laboratory Analyses

1. Particle Size Distribution

Several workers have reported that particle size distribution is related to slope position. Franzmeier *et al.* (1969), reported that soils in the middle slope position are higher in coarse material than those in the upper or lower positions. This conclusion was based on an investigation of soils on slopes ranging from 36 to 62 percent.

The distribution of sand, silt, and clay for the seven sites is reported in Figures 4a to 4c. The difference in distribution reflects pedogenesis more strongly than deposition.

At site 6 in the present investigation, the Ae horizon is thicker than the Ae horizons of the other north-facing sites and the crown position. The clay content of the Ae at site 1 is 11 percent as compared to 5 percent at site 6. However, the clay content of the Bt at site 6 is 40 percent and only 33 percent at site 1. This indicates that more leaching has occurred at site 6 than at site 1. A similar relationship exists between site 6 and sites 2 and 4. More moisture from run-off is available at site 6 resulting in increased

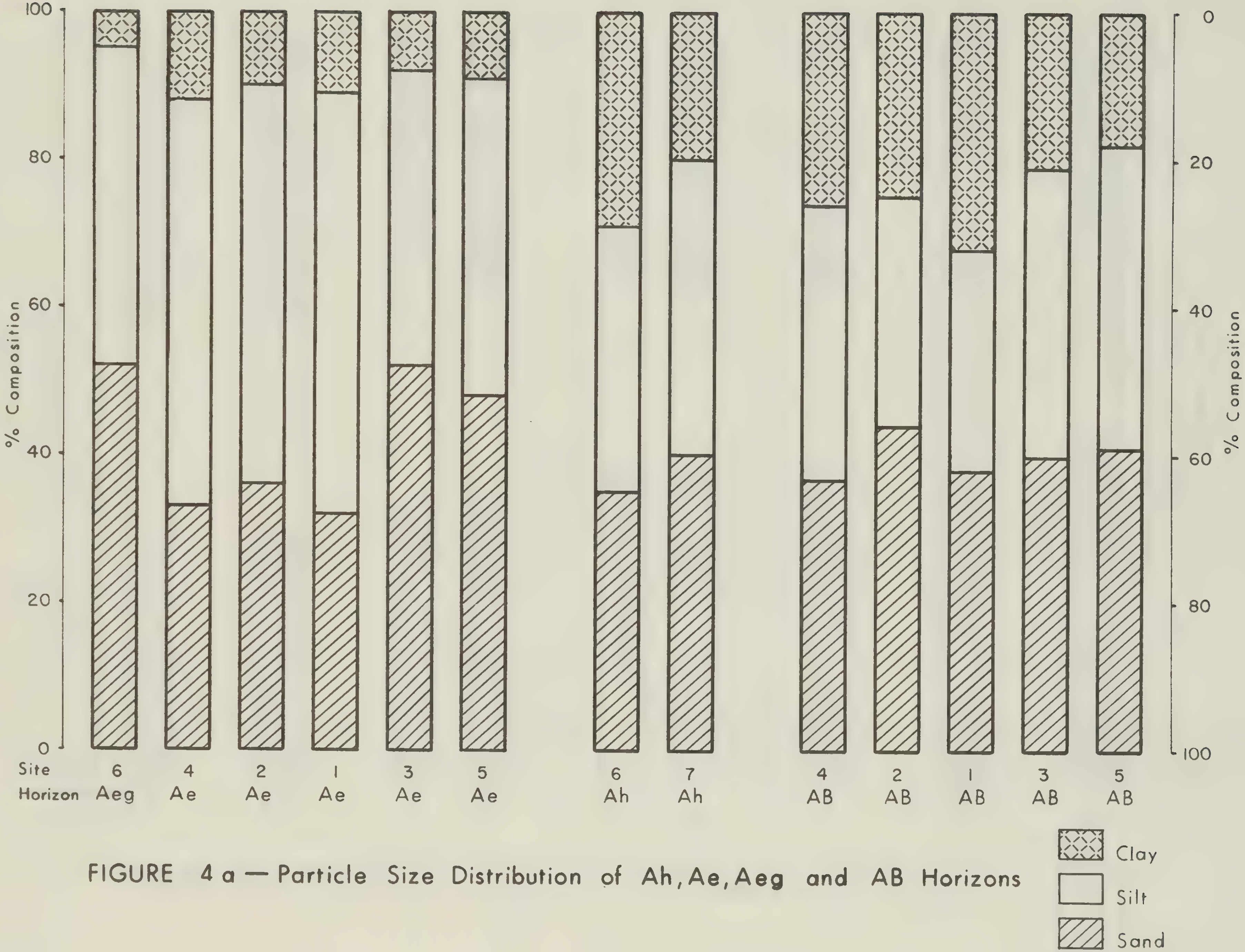


FIGURE 4 a — Particle Size Distribution of Ah, Ae, Aeg and AB Horizons

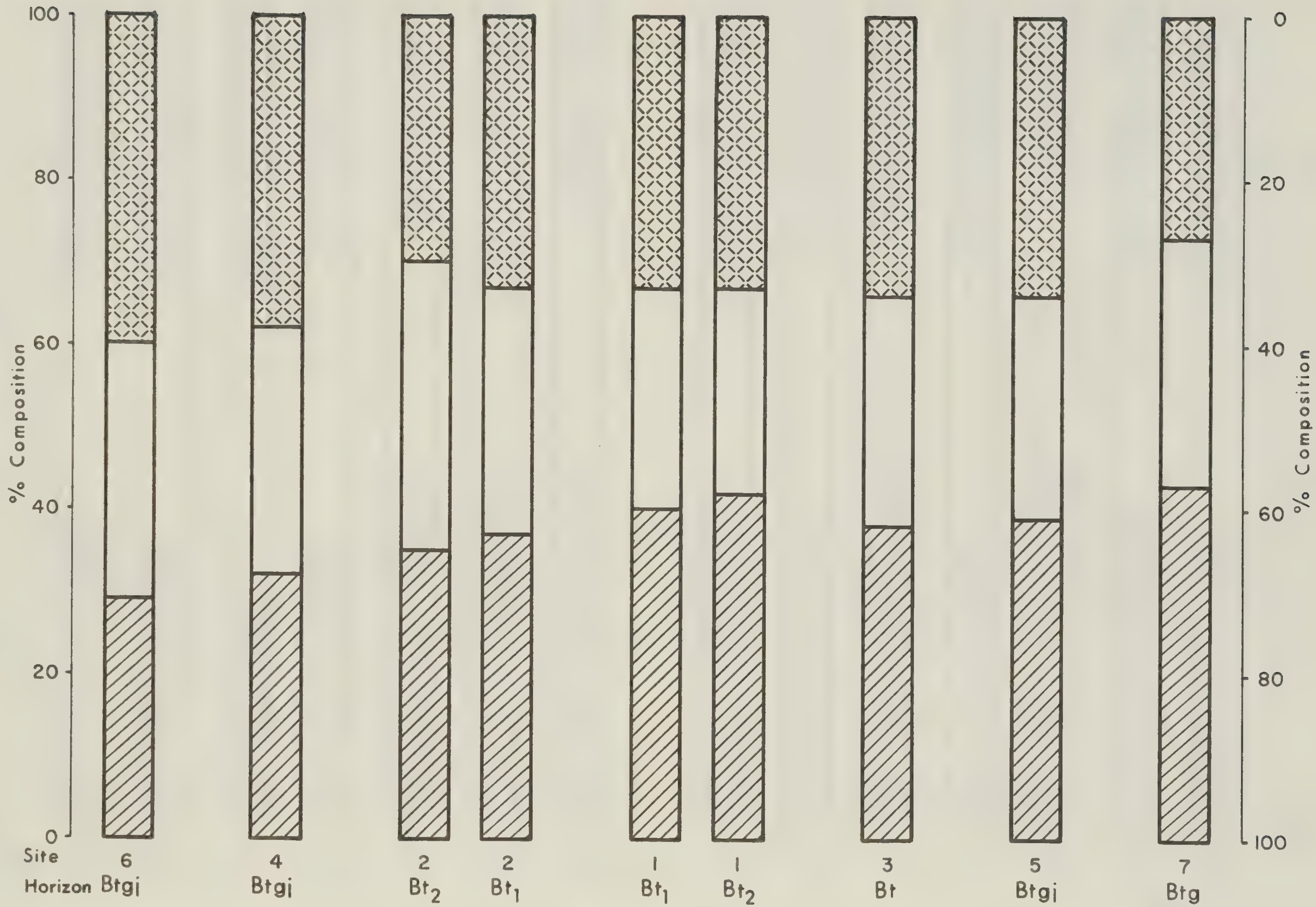


FIGURE 4b — Particle Size Distribution of Bt, Btgj and Btg Horizons

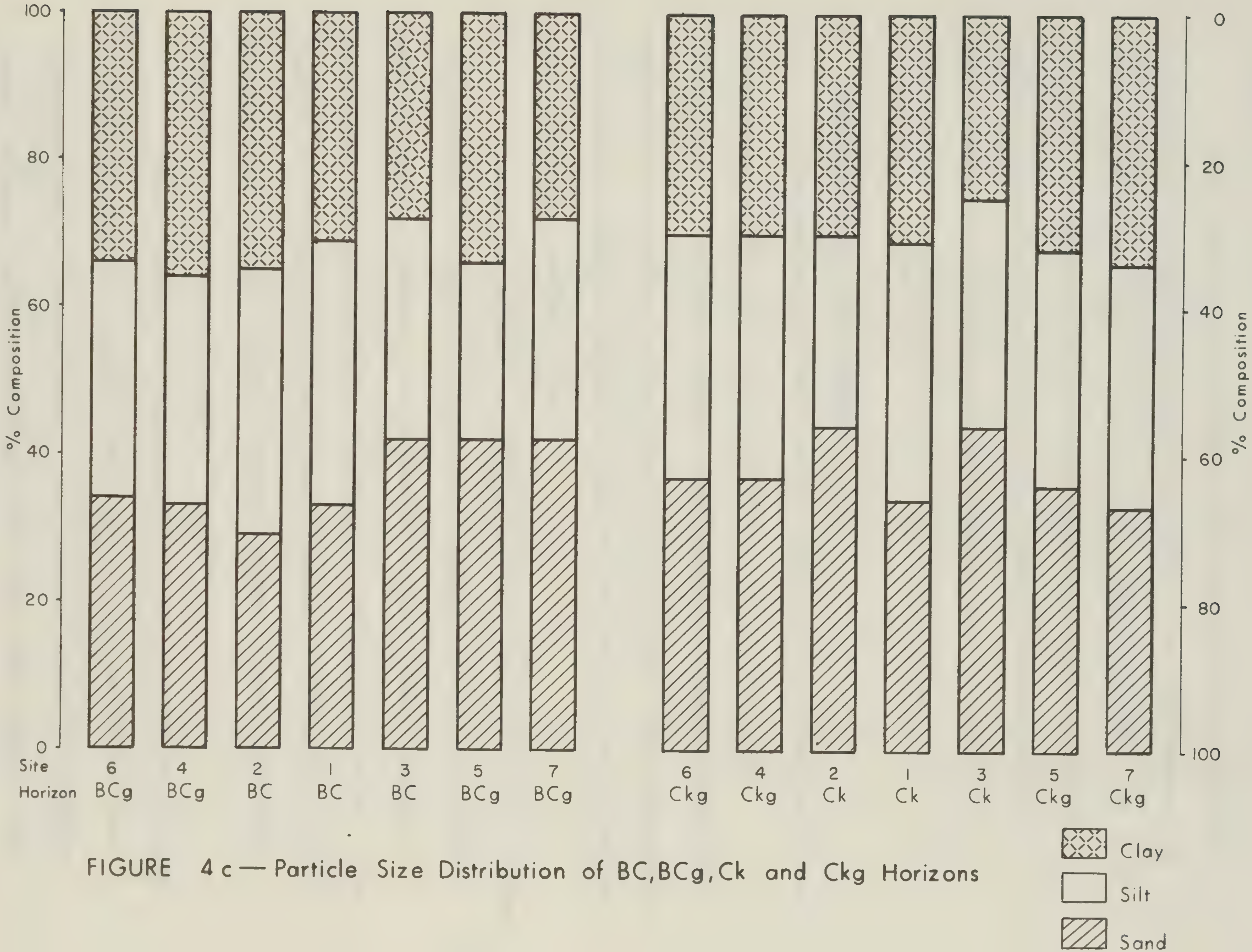


FIGURE 4 c — Particle Size Distribution of BC, BCg, Ck and Ckg Horizons

leaching.

The results also indicate a difference in leaching between the north- and south-facing slopes. At site 4, the clay content in the Ae is 12 percent and 38 percent in the Btgj. At site 5, the clay content is 9 percent in the Ae horizon and 34 percent in the Btgj horizon. The Ae is 15 cm thick at site 4 and 10 cm thick at site 5. Higher evaporation rates on the south-facing slope may result in lesser amounts of moisture available for leaching downward.

2. Extractable Iron and Aluminum

The processes of soil genesis affect the distribution of iron and aluminum in the soil. An approximation of the degree of accumulation of amorphous products from recent weathering in soils is provided by the oxalate values. The dithionite iron values approximate the combined content of amorphous forms of iron and of crystalline iron oxides (McKeague and Day, 1966).

Data for oxalate- and dithionite-extractable iron and aluminum are presented in Figure 5. These data indicate a relatively similar and low aluminum content. The values for oxalate- and dithionite-extractable iron and aluminum are generally similar at the seven sites. Despite the strong mottling and gleying features exhibited by the soils at site 6 and 7 there is only a slight increase in dithionite iron compared to the soils at the other five sites.

These results for extractable iron and aluminum are similar to those reported for Luvisolic and Gleysolic soil in Saskatchewan by Stonehouse and St. Arnaud (1971). In a study of soils from Eastern Canada, McKeague and Day (1966) noted that many Humic Gleysols and

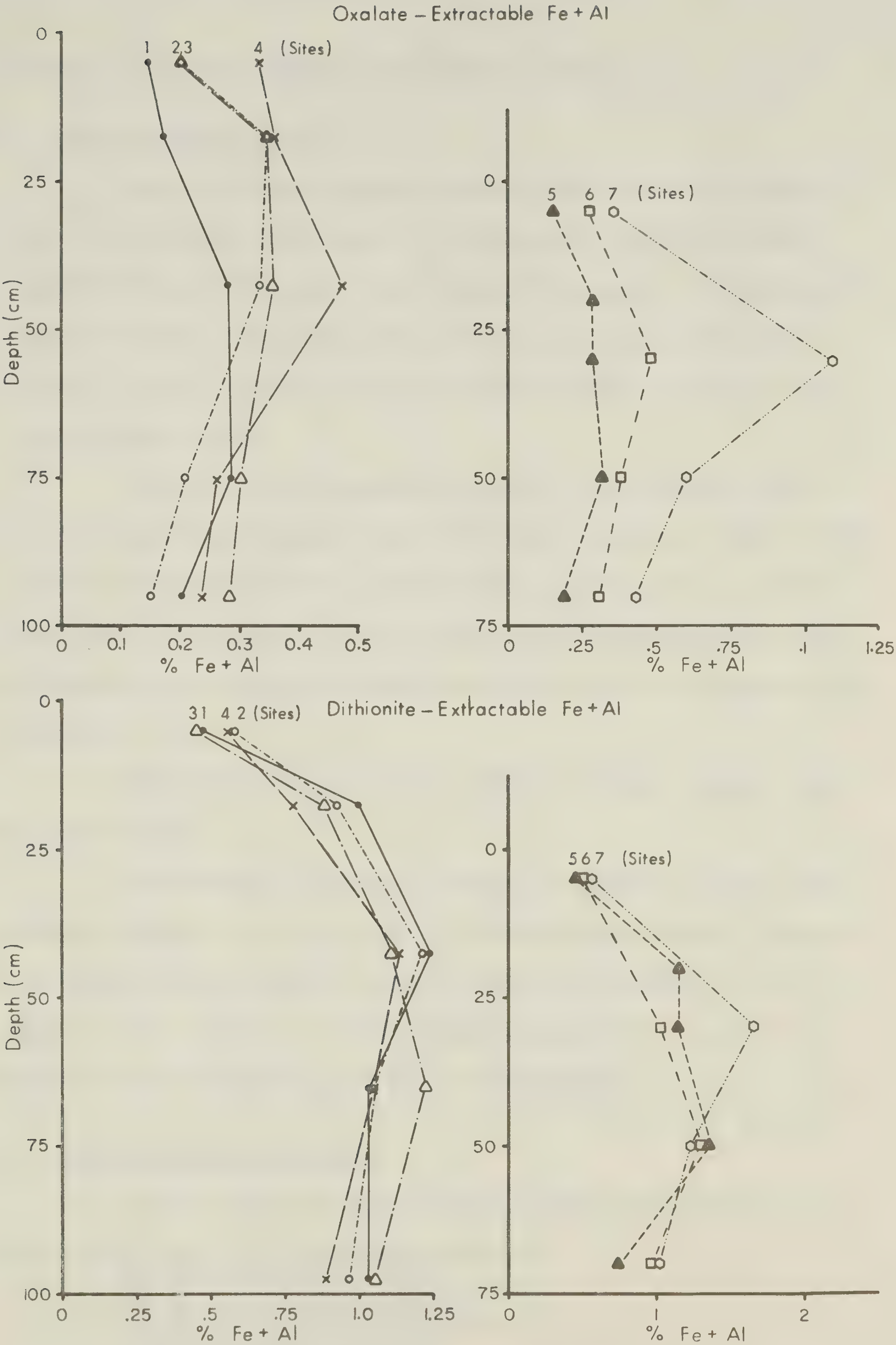


FIGURE 5 — Extractable Iron and Aluminum

Gleysols had weakly expressed profiles of Fe and Al.

3. Cation Exchange Capacity

Data for cation exchange capacity are reported in Table 9. There is no apparent difference in total exchange capacity between comparable mineral horizons of the various soil pedons. The organic L-H horizon is an exception. The variability in the L-H horizons probably results from the differing nature or amounts of leaf litter at the various sites.

The ratio of exchangeable calcium to magnesium was high in the L-H horizons and became lower in the other horizons. Pawluk (1960) reported similar results in a study of Gray Wooded soils in the Peace River area. He suggested that the high ratio of exchangeable calcium to magnesium in the surface organic matter reflects the composition of the forest litter.

The base saturation of the profiles was high, ranging from 83 to 96 percent.

Exchangeable calcium was present in relatively high quantities and occupied 53 to 83 percent of the exchange complex. Exchangeable magnesium was present in lesser amounts and occupied 4 to 36 percent, while sodium and potassium each accounted for less than 2 percent of the exchangeable cations on the complex.

4. Clay Mineralogical Analyses

X-ray diffraction patterns were obtained for oriented slides of K and Mg clays. The treatments used were:

(a) Mg saturated-air dried;
(b) Mg saturated-glycolated;
(c) Mg saturated-heated to 550° C;
(d) K saturated-air dried;
(e) K saturated and heated to 550° C.

TABLE 9 - Cation Exchange Capacity and Exchangeable Cations

		me./100g					CEC (me./100g)	
Horizon	Site	H	Na	K	Ca	Mg	Sum	Det.
L-H	1	8.3	0.1	1.6	39.5	3.5	53.0	48.7
L-H	2	11.4	0.1	1.8	42.8	6.7	60.8	59.3
L-H	3	7.3	0.1	1.6	39.5	3.5	52.0	48.7
L-H	4	14.5	0.1	2.9	73.0	9.8	100.3	95.1
L-H	5	4.5	0.2	2.0	65.0	10.0	81.7	78.1
L-H	6	4.7	0.1	2.0	28.7	5.8	41.3	45.6
L-H	7	4.0	0.4	2.0	99.0	14.6	120.3	111.2
Ae	1	1.5	0.2	0.2	5.2	0.3	7.4	7.0
Ae	2	2.0	0.1	0.2	5.4	0.4	8.1	7.6
Ae	3	1.4	0.1	0.3	4.0	1.3	7.1	6.9
Ae	4	1.8	0.2	0.2	5.0	1.7	8.9	8.3
Ae	5	1.1	0.1	0.2	5.9	2.3	9.4	8.4
Aeg	6	1.2	0.1	0.1	4.7	0.6	6.7	5.7
AB	1	2.0	0.1	0.4	8.9	4.3	15.7	15.0
AB	2	1.7	0.1	0.4	9.4	5.5	17.1	16.2
AB	3	1.4	0.1	0.4	9.9	1.6	13.3	12.5
AB	4	2.4	0.1	0.3	8.4	4.6	15.8	15.4
AB	5	0.7	0.2	0.3	14.4	2.6	18.2	16.6
Bt	1	2.6	0.1	0.4	11.4	5.4	19.9	19.6
Bt	2	3.4	0.1	0.4	12.9	5.8	22.6	22.6
Bt	3	1.4	0.2	0.7	16.8	4.3	23.2	22.5
Btgj	4	3.1	0.4	0.5	14.6	8.4	27.0	27.1
Btgj	5	0.6	0.1	0.4	19.3	5.9	26.3	24.5
Btg	6	2.7	0.1	0.5	16.1	10.3	29.7	27.3
Btg	7	-	0.4	0.2	15.8	4.8	20.9	23.1
BC	1	2.0	0.1	0.4	17.1	6.4	26.0	24.1
BC	2	2.8	0.2	0.4	15.3	9.7	28.4	26.1
BC	3	0.8	0.1	0.5	13.9	4.3	19.5	18.8
BCg	4	1.7	0.4	0.5	14.9	10.3	27.7	25.2
BCg	5	-	0.1	0.4	18.8	5.2	24.5	21.9
BCg	6	-	0.2	0.4	14.4	8.6	23.6	23.6
BCg	7	-	0.1	0.4	16.8	3.8	21.2	19.4

The X-ray data suggests that the clay mineral composition in the seven pedons was similar with only minor differences in distribution among the various horizons (Table 10). Montmorillonite, which was common to all horizons, was dominant in the Bt horizons. It occurred in much lower quantites in the Ae horizons mainly as a "mixed layer" structure rather than as discrete particles. Illite was also present in all horizons.

It was difficult to assess the presence of kaolinite in the X-ray patterns because of the coincidence of a possible second order peak for chlorite and a first order peak for kaolinite. The 7Å peak which collapses upon heating to 550° C may indicate that there is some kaolinite present, however such collapse has been reported for chlorite as well (Brown, 1961).

Mixed layer structures were most evident in Ae horizons and exhibited variable expansion upon glycolation. These structures showed a broad plateau from 14Å up to as high as 30Å with minor peaks at irregular intervals. Upon heating to 550° C the structures collapsed to 10Å spacings. Minerals showing these characteristics result from random and regular interstratification of illite and montmorillonite (Pawluk, 1960).

Quartz was estimated from the intensity of the 4.26Å peak. It was detected in all horizons but appeared to be most abundant in the Ae horizons.

TABLE 10 - Mineral Species Present in the Clay Fractions of Selected Horizons as Estimated from X-ray Patterns

Site	Horizon	Mont.[1]	Illite	Kaol.+Chlor.[2]	Quartz	Mixed Layer
1	Ae	xx[3]	xx	x	x	xx
	Bt	xxx	xx	x	x	xx
	Ck	xxx	x	x	x	x
2	Ae	xx	xx	x	x	xx
	Bt	xxx	x	x	x	xx
	Ck	xx	xx	x	x	x
3	Ae	xx	xx	x	x	xx
	Bt	xxx	xx	x	x	x
	Ck	xxx	xx	x	x	x
4	Ae	xx	x	x	x	xx
	Btgj	xxx	x	x	x	x
	Ckg	xxx	xx	x	x	x
5	Ae	xxx	x	x	x	xx
	Btgj	xxx	xx	x	x	x
	Ckg	xxx	x	x	x	x
6	Ah	xx	x	x	x	xxx
	Btg	xx	xx	x	x	xx
	Ckg	xxx	xx	x	x	xx
7	Ah	xxx	xx	x	x	xx
	Btg	xxx	x	x	x	xx
	Ckg	xxx	xx	x	x	x

[1] Mont. - montmorillonite

[2] Kaol.+Chlor - kaolinite + chlorite

[3] relative quantities x - trace (<10%)
xx - minor (10-40%)
xxx - dominant (>40%)

Part B Discussion of Field Data

1. Soil Reaction

The pH was measured in the A, B, and C master horizons at each of the sites at frequent intervals throughout the duration of the study. These measurements were made to determine whether there was a significant seasonal variation in pH at the sites.

Figures 6a to 6d show the fluctuations that occurred in the various horizons at each of the sites. The highest pH value usually occurred in the spring. These results are similar to those of Bowser and Leat (1958) who studied similar soils east of Edmonton. They found large differences of up to 2 pH units between spring and fall readings. In this study, the largest difference between maximum and minimum seasonal pH readings was 1.3 units in the BC horizon at site 1. The smallest difference was 0.2 units in the Ck horizon at site 6. The fluctuations were similar in the Ah, Ae, Bt, and BC horizons, while those in the Ck were of lesser magnitude. Over the two seasons the Ah horizons fluctuated 0.7 pH units. The Ae, Bt, BC, and Ck horizons (including gleyed members) showed fluctuations of 0.8, 0.7, 0.8, and 0.5 pH units respectively.

Fluctuations in pH are probably related to the variation in moisture content and temperature over the growing season. In general, pH values decreased as moisture content decreased and as temperature of the soil increased. Changes in microbial activity could have some effect on the fluctuations in pH because temperature regime and moisture regime are important factors in determining the level of microbial activity.

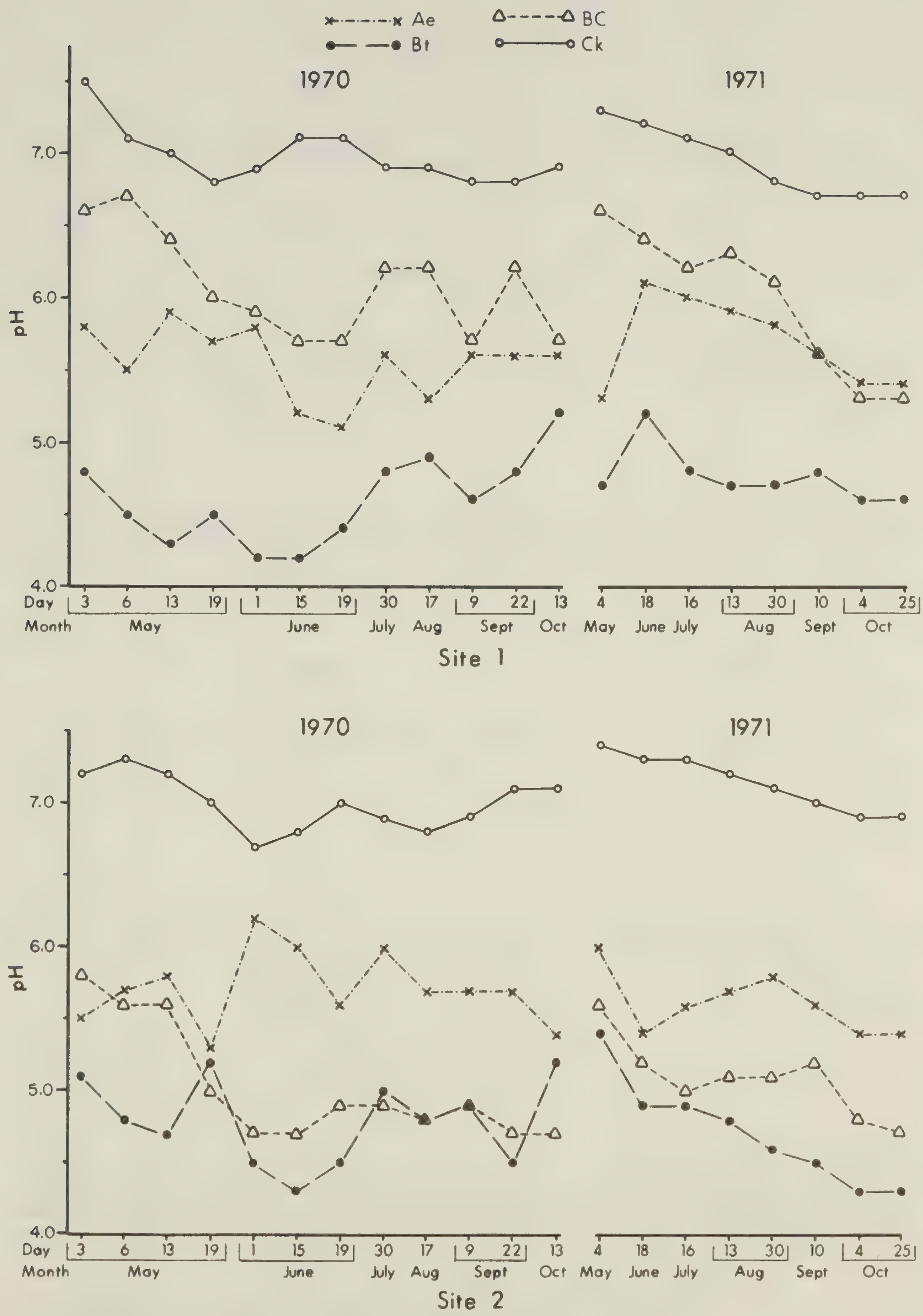


FIGURE 6 a — pH of Four Horizons at Sites 1 and 2

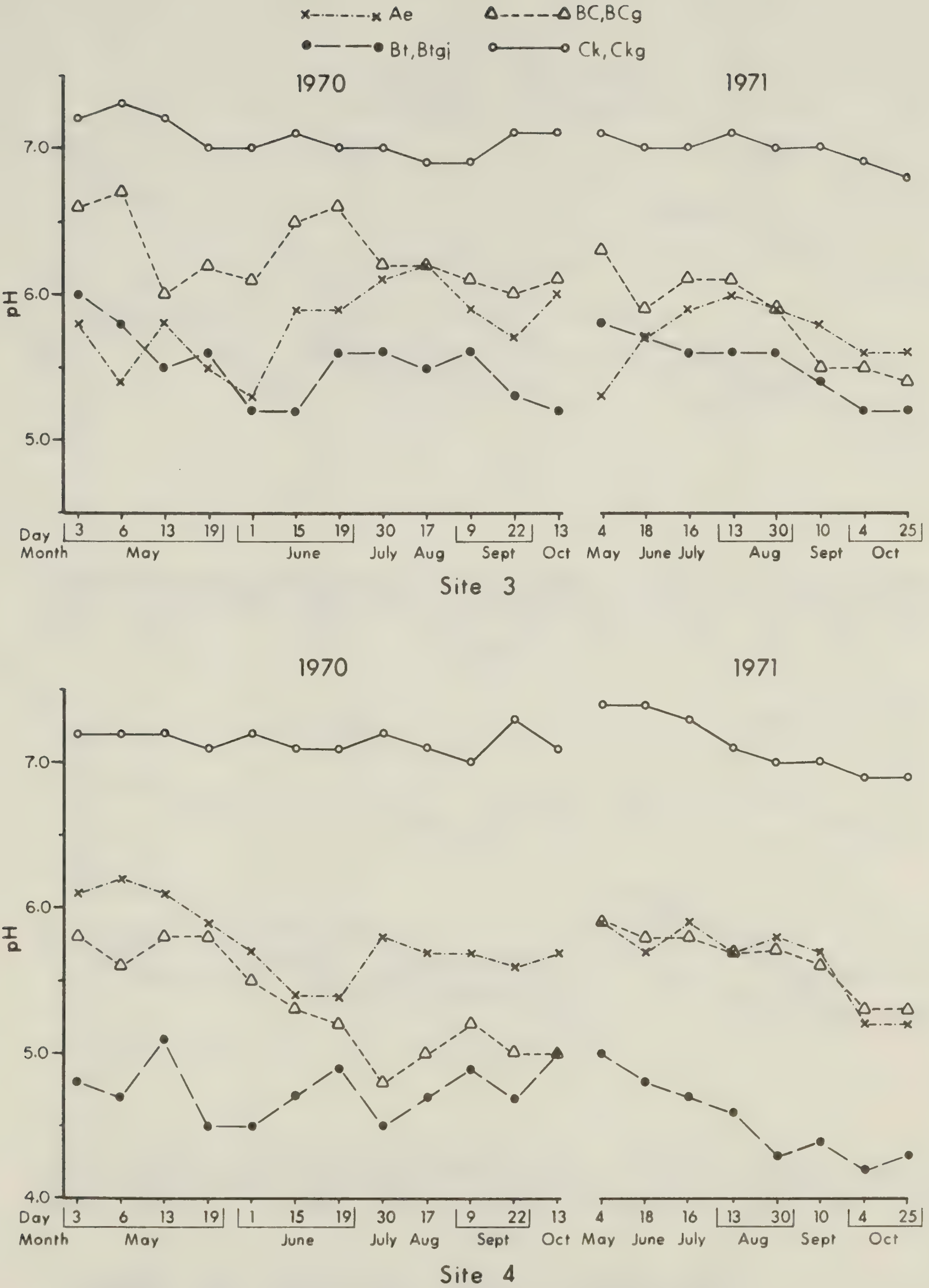


FIGURE 6b — pH of Four Horizons at Sites 3 and 4

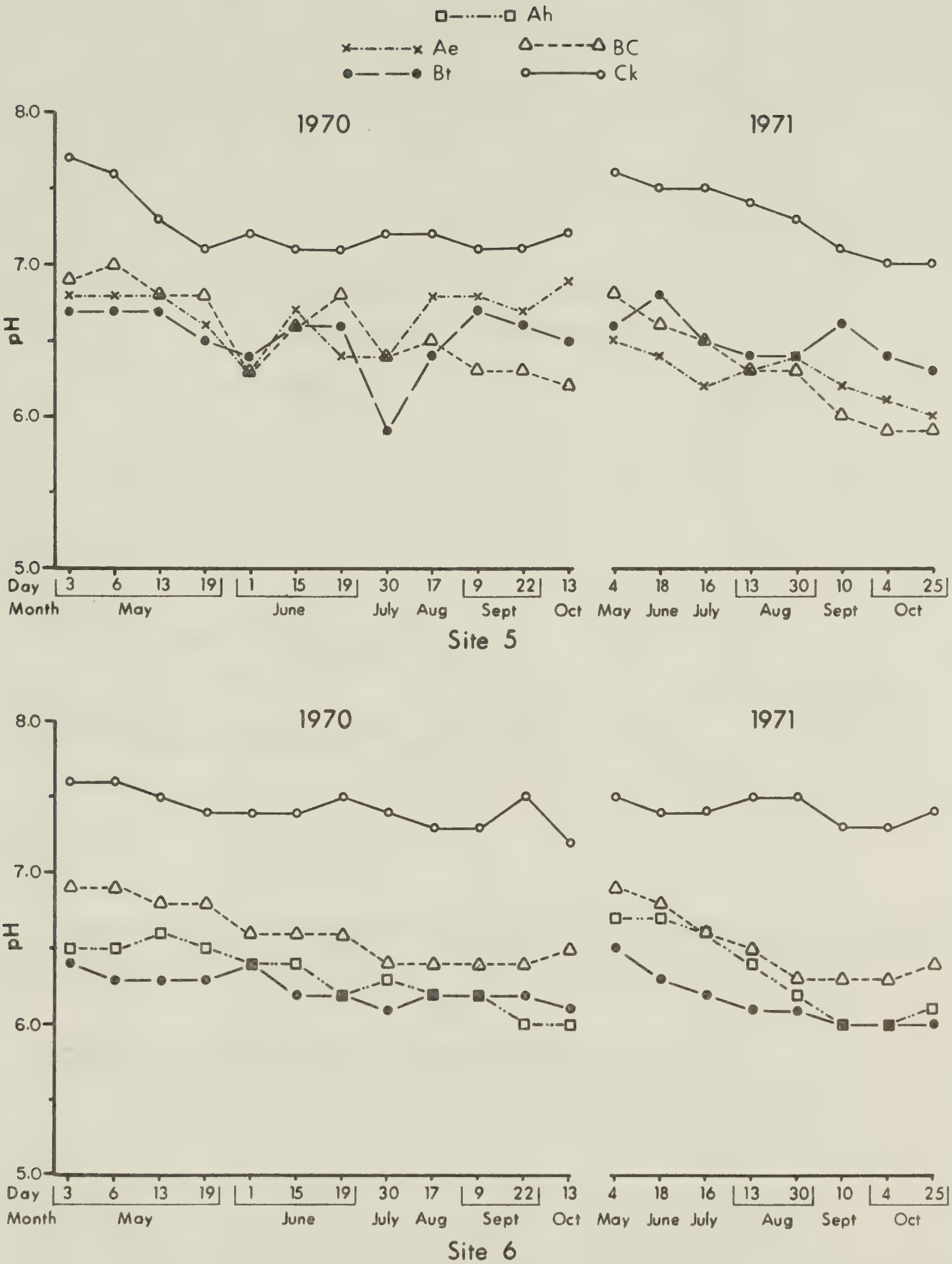


FIGURE 6 c — pH of Four Horizons at Sites 5 and 6

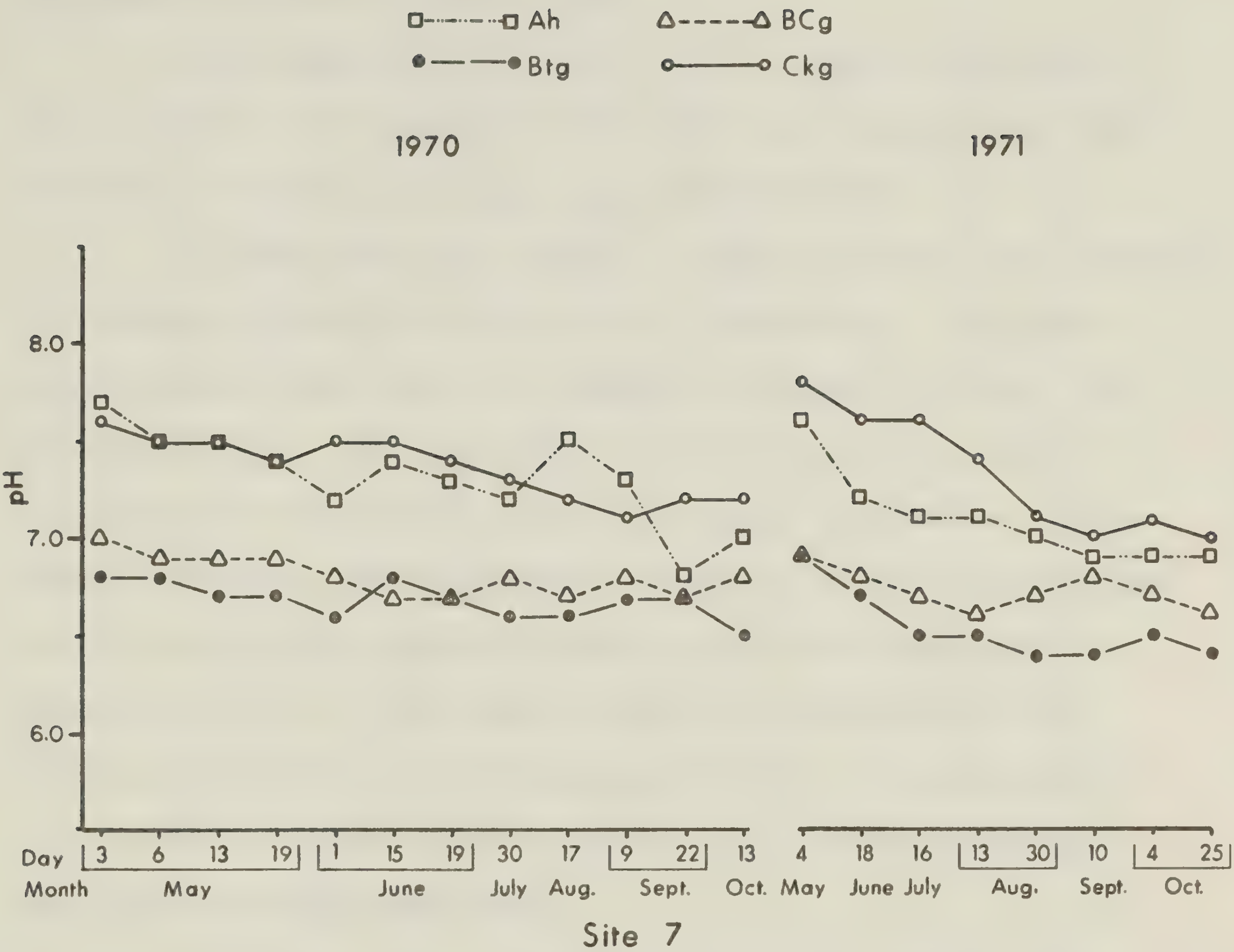


FIGURE 6 d — pH of Four Horizons at Site 7

2. Soil Temperature

(a) Seasonal Variation in Temperature with Depth and Aspect

Figures 7a and 7b depict the mean monthly soil temperatures at the 10, 30, 50, and 100 cm depths from May to October at the seven sites. The means were calculated from values obtained during the May to October intervals in 1970 and 1971.

Soil temperature varies with depth. Seasonal variations of soil temperature were greatest at the surface and decreased with depth. Generally, in summer temperature decreased with depth.

In the transitional seasons of spring and autumn, peculiarities were observed in the distribution of soil temperature. For example, in the spring a cool layer was "sandwiched" between warmer upper and lower soil layers. Low temperatures measured at the 50 cm depth in May reflect the transitional stage of the temperature profile between winter and summer. The temperatures of the soil at the 30 cm depth and the 100 cm depth were higher than those at the 50 cm depth with the exception of site 3. This could be explained by the fact that the warming temperatures of the spring season have not yet penetrated the soil to the 50 cm depth and the temperature at the 100 cm depth had been higher throughout the winter.

The highest soil temperature at all depths and at all sites was reached during the month of August. During June, July, and August the largest variation in soil temperature between the various depths occurred. The temperatures at the 30 cm depth in August were approximately equivalent to those in July at the 10 cm depth. Similarly, the soil temperatures at the 100 cm depth in August were approximately the same as those at the 50 cm depth in July. This

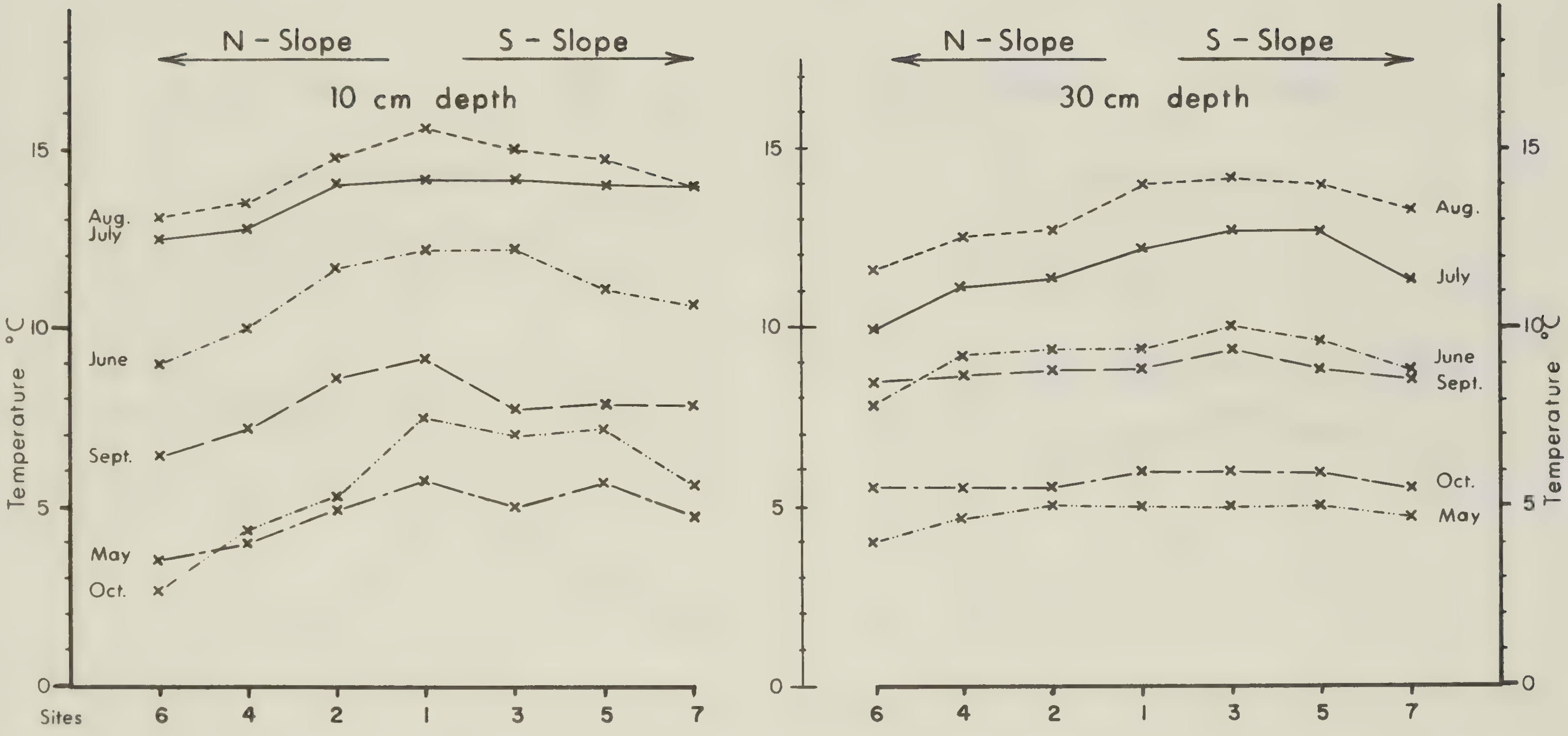


FIGURE 7 a — Mean Monthly Soil Temperatures at the 10 and 30 cm Depths

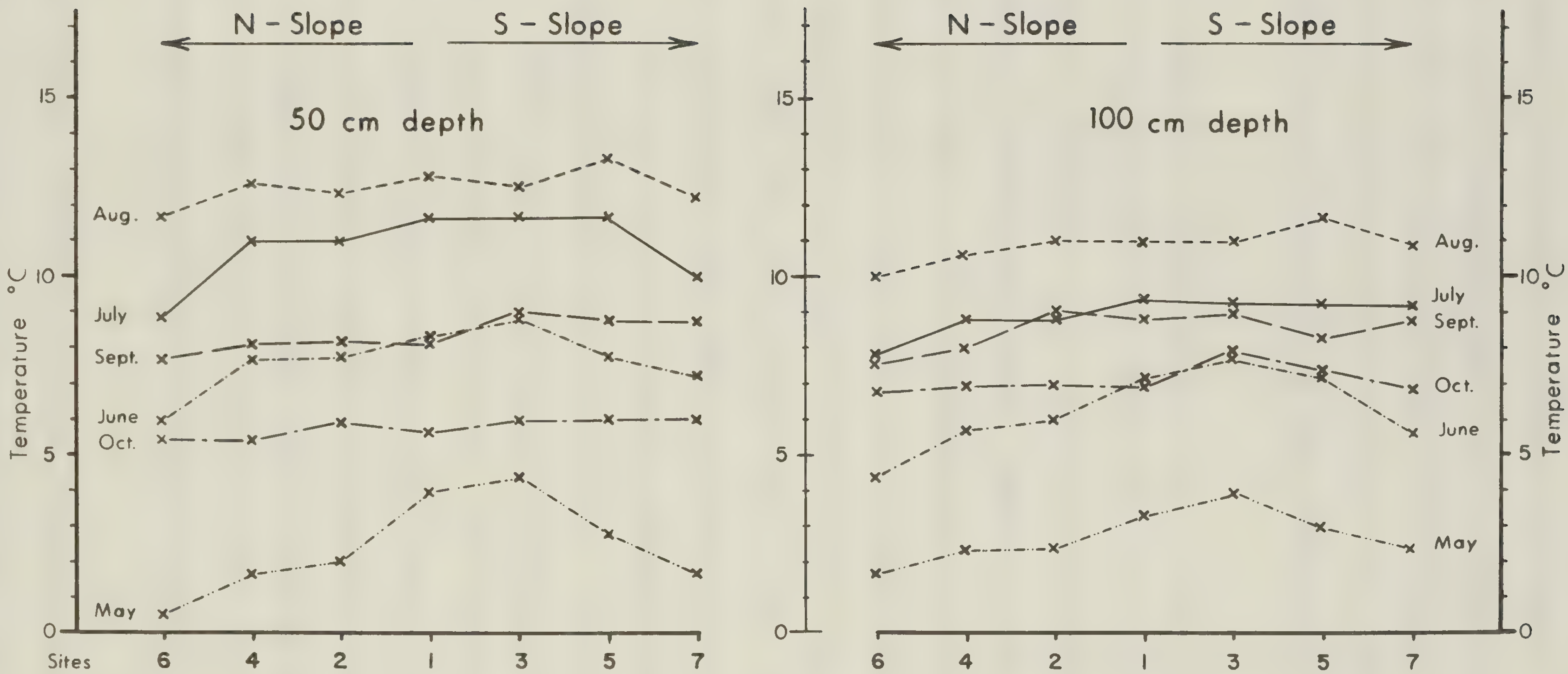


FIGURE 7 b — Mean Monthly Soil Temperatures at the 50 and 100 cm Depths

relationship changed in the months of September and October. The least variation in soil temperature among the four depths occurred in September. The spread in temperature values became larger in October with the highest soil temperature recorded at the 100 cm depth. This indicates a faster rate of cooling in the upper layers than in the lower layers.

Soil temperature at three depths at site 1 were compared to soil temperature data collected under aspen tree cover by the Soil Science Department at Ellerslie (J. A. Toogood, personal communication). Figure 8 represents a comparison of the soil temperature at the 20 and 100 cm depths at Ellerslie with the temperatures at the 10, 30, and 100 cm depths at site 1 of the study area. The monthly soil temperatures represent a two year mean of 1970 and 1971 values. The intention of this comparison is to show the trends in soil temperature at various depths at both locations rather than compare the actual temperatures. It would be difficult to make a meaningful comparison of the soil temperatures because the areas are different in several respects. The relatively bare soil surface at Ellerslie is level and the aspen tree cover is less than 15 feet high. Soil temperatures were measured at different times in the two areas; daily at Ellerslie and twice weekly in this study. However, the seasonal differences in the change of soil temperature with depth follow a similar pattern in the two areas. For example, both areas exhibited higher soil temperatures at the 100 cm depth than at shallower depths in September and October.

Bowser and Leat (1958) collected soil temperature data at the 10 cm depth of a Luvisolic soil having aspen as the main vegetative

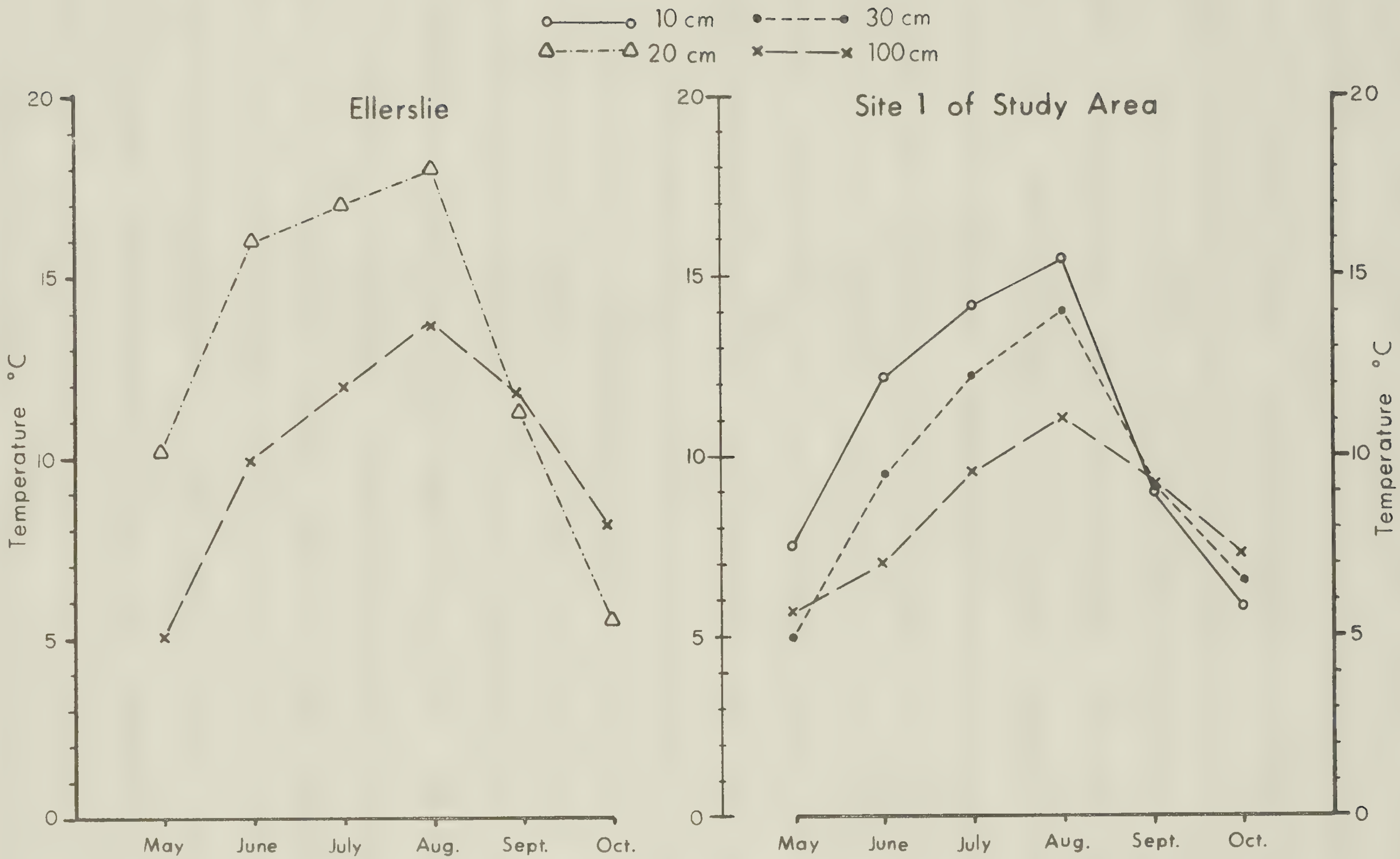


FIGURE 8 — Mean Monthly Soil Temperatures at Various Depths at Ellerslie and Site 1 of the Study Area

cover. They made weekly measurements from May to October of 1954 and 1955, and found the mean soil temperature to be 10.5° C. At Ellerslie, the mean soil temperature at 20 cm from May to October of 1970 and 1971 was 11.9° C. During the same six month interval in 1970 and 1971 the mean soil temperature at 10 cm at site 1 of the study area was 10.6° C.

The data presented above represent three different areas involving different depths. The soils studied by Bowser and Leat were similar to the soils investigated in this project and were characterized by a native vegetative cover. However, the temperatures were recorded at different times of the day; at 5 AM at Ellerslie and in the mid-afternoon by Bowser. Therefore, the difference in the mean soil temperatures indicates that soils under a natural forest cover including shrubs and herbs are cooler than soils with a more scant cover.

Differences resulting from aspect are depicted in Figures 7a and 7b. In addition, the differences between the 10 cm depth at site 4 on the north-facing slope and site 5 on the south-facing slope are illustrated in Figures 9a and 9b. The soil temperature was higher on the south-facing slope than on the north-facing slope. The difference in soil temperature between the two aspects was smallest during the months of July and August and largest during May, June, September, and October. For the May to October period in 1970, the mean soil temperature was 9.1° C at site 4 and 11.3° C at site 5. For the same period in 1971, the mean temperature was 8.8° C at site 4 and 10.8° C at site 5.

Between temperatures of 0° C and 5° C root growth of most plants and germination of most seeds does not occur (U.S.D.A., 1964). The soil begins to come to life after its temperature exceeds 5° C.

The Canada Soil Survey Committee (1970) selected the 5° C temperature at the 50 cm depth as the temperature for separating the soil biosystem into active and relatively inactive periods. Vorobieva (1961) noted that the minimum temperature for the root growth of a species of birch (Betula) was about 5° C. Since birch and aspen (Populus tremuloides) grow in intimate association, one would expect this critical temperature to be similar for both species.

Data in the appendix indicate that the soil temperature at the 50 cm depth at site 3 reached 5° C on May 21 in 1970 while the soil temperatures at the same depth at the other sites were below this temperature. It was not until June 8 that all seven sites were 5° C or warmer at the 50 cm depth. May, 1971 was generally warmer than May, 1970 resulting in the soil temperature reaching 5° C at the 50 cm depth at site 3 on May 10. All sites had reached 5° C by May 31. In both years the soil at site 6 warmed more slowly. These data indicate that the growing season is at least one week longer on the south-facing slope than on the north-facing slope. In a similar study, MacHattie and McCormack (1961) noted that flowering of plants occurred first on the ridgetop, next on the south slope, and last on the north slope, about seven days after the ridgetop. They also noted that towards the end of August the leaves began turning color in the reverse order.

(b) The Relationship Between the Temperature of Air and Soil

Shul'gin (1957) states that the mean annual soil temperature is always above the mean annual air temperature. The difference between air and soil temperature varies in amount according to climatic zones.

Figures 9a and 9b show the relationship between the soil temperature at the 10 cm depth at sites 1, 4, and 5 and air temperature measured at Stony Plain. Air temperatures from Stony Plain (Dept. of Transport Met. Records) were used in this comparison because of the proximity of the study area to Stony Plain. From a comparison of air temperatures at Edmonton International and Industrial Airports during May to October of 1971, it was noted that the temperature difference between these two locations was about 1° C. Because of this minor difference in temperature, it is felt that the use of the Stony Plain data to characterize the air temperature of the study area would be valid. The air temperatures plotted in Figures 9a and 9b were computed from mean daily air temperatures by employing a weight factor for the specific day and three preceding days. For example, to compute the air temperature for June 5, the mean temperature for that day would be multiplied by a weight factor of 4; for June 4, the weight factor would be 3; for June 3, it would be 2; and for June 2, the factor would be 1. This cumulative total is divided by 10 to arrive at the air temperature. This method was employed to account for the lag factor which exists because soils warm up less rapidly than air.

The figures indicate that air temperature fluctuated more widely than the soil temperature. Also, air temperature was usually higher than the soil temperature throughout the study period. The mean air temperature from May to October in 1970 was 14.2° C and in 1971 the mean was 13.5° C. The mean soil temperature from May to October at the 10 cm depth at site 1 was 10.6° C in 1970 and 10.5° C in 1971.

Bowser and Leat (1958) reported a similar relationship

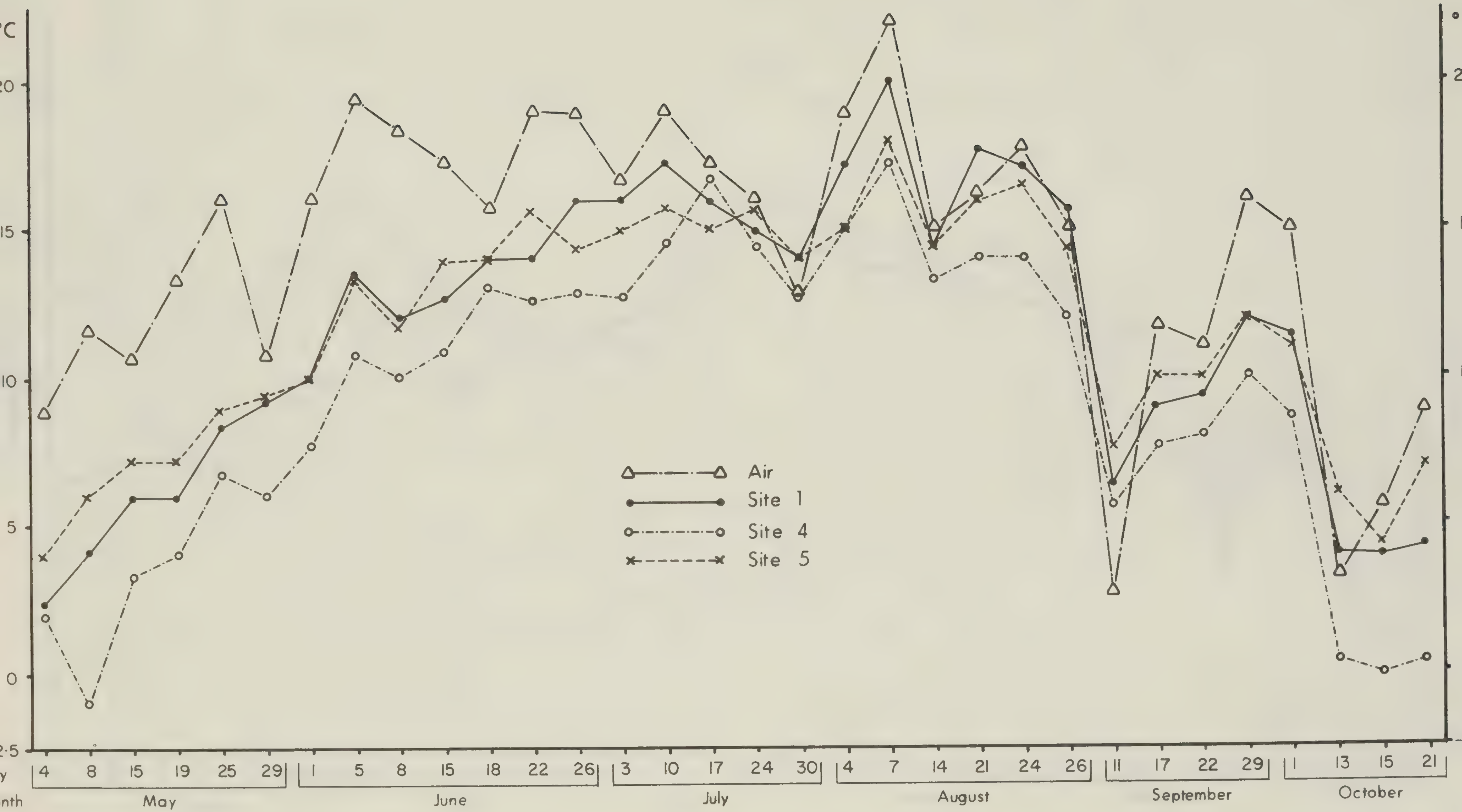


FIGURE 9a — Air Temperature and Soil Temperature at the 10 cm Depth at Sites 1, 4, and 5 in 1970

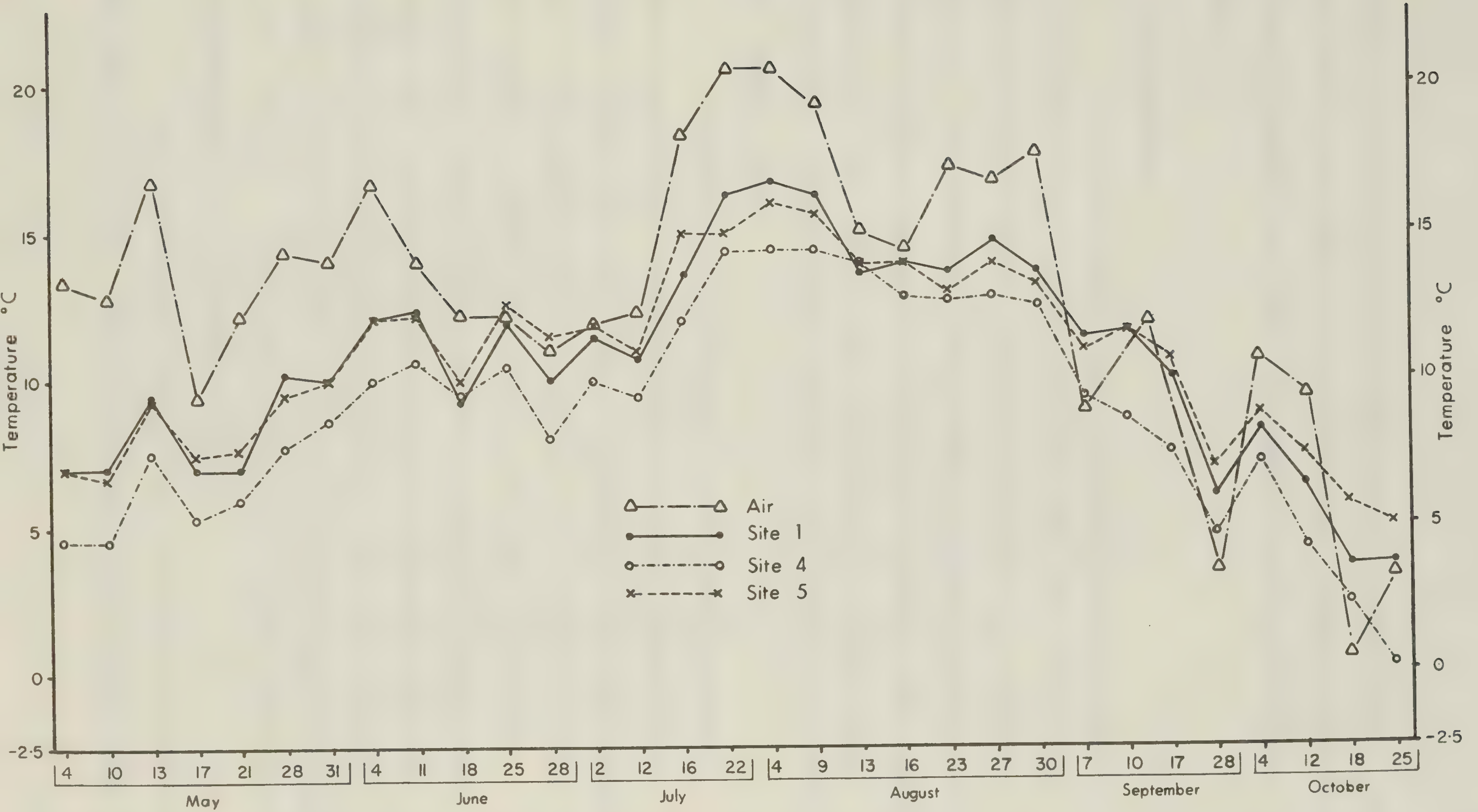


FIGURE 9b — Air Temperature and Soil Temperature at the 10 cm Depth at Sites 1, 4, and 5 in 1971

between air temperature and soil temperature at the 10 cm depth. These data indicate that under natural vegetation soil temperature at the 10 cm depth is usually lower than air temperature during the growing season.

3. Soil Moisture

Atmospheric precipitation is the most important source of soil moisture. After reaching the land surface, the moisture from precipitation may evaporate, run off into depressions, or seep into the soil. This atmospheric precipitation is important because of its moistening effect, upon which the entire soil forming process largely depends (Volobuev, 1963). Figure 10 represents the precipitation measured at a cleared location within the study area for the 1970 and 1971 growing seasons.

Figures 11a to 11d represent the mean monthly moisture contents expressed as a percentage for the 10, 30, 50, and 100 cm depths at each of the seven sites. In addition, the monthly precipitation data measured at each site are presented. Widest variations over the six month period were observed at sites 4 and 5, with lesser variations at the moderately well drained and poorly drained sites. During 1970, the moisture content was generally highest in May and decreased throughout the following months. In May, the moisture content at site 1 at the 100 cm depth was 30 percent higher than that at the 10 cm depth. The difference in moisture content between these two depths narrowed to 6 percent in October.

Total precipitation during the same six month period in 1971 was higher than in 1970, especially in the months of June and July.

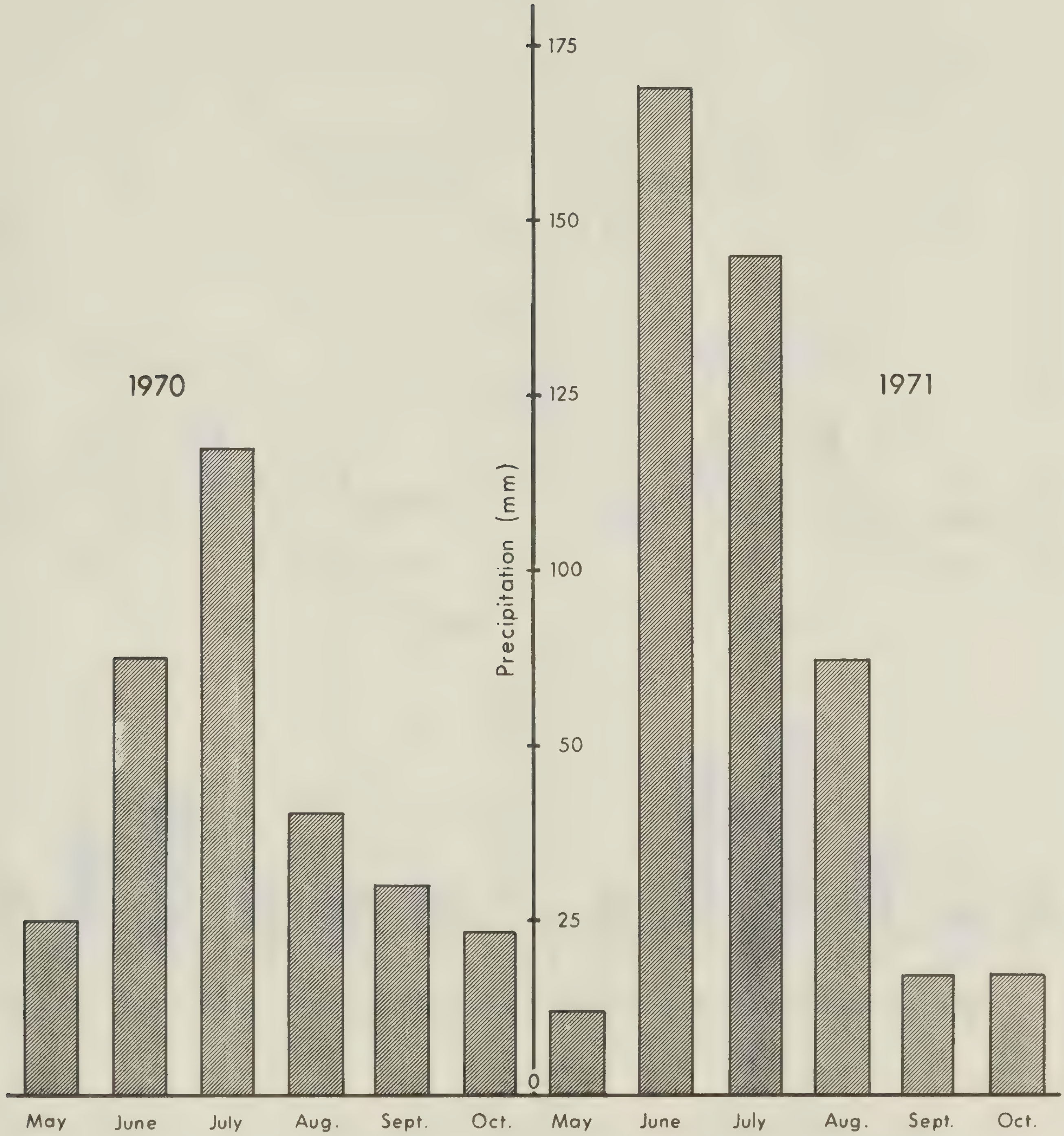


FIGURE 10 — Total Precipitation Measured at the Control Gauge Site

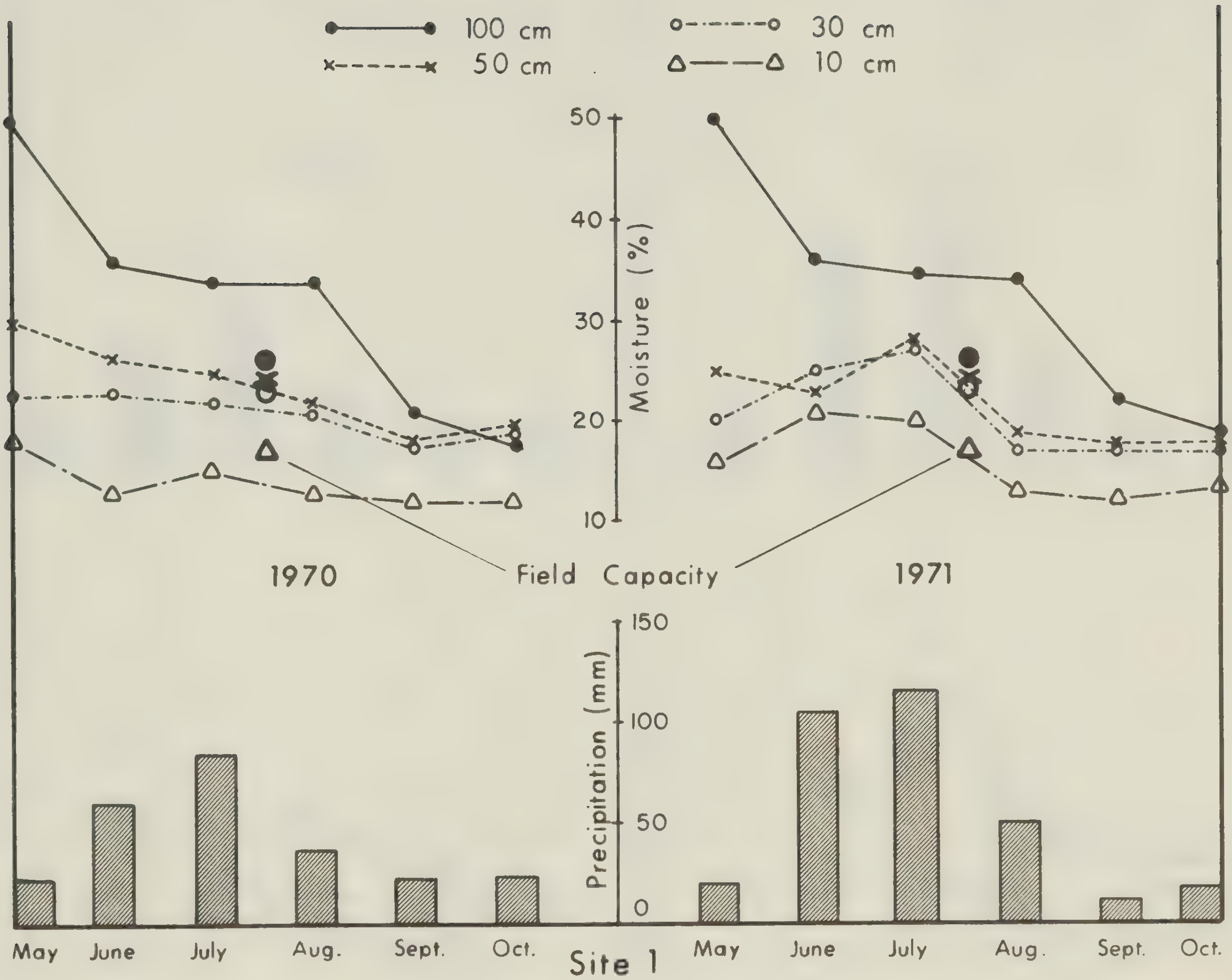


FIGURE 11a — Mean Monthly Moisture Contents and Precipitation at Site 1

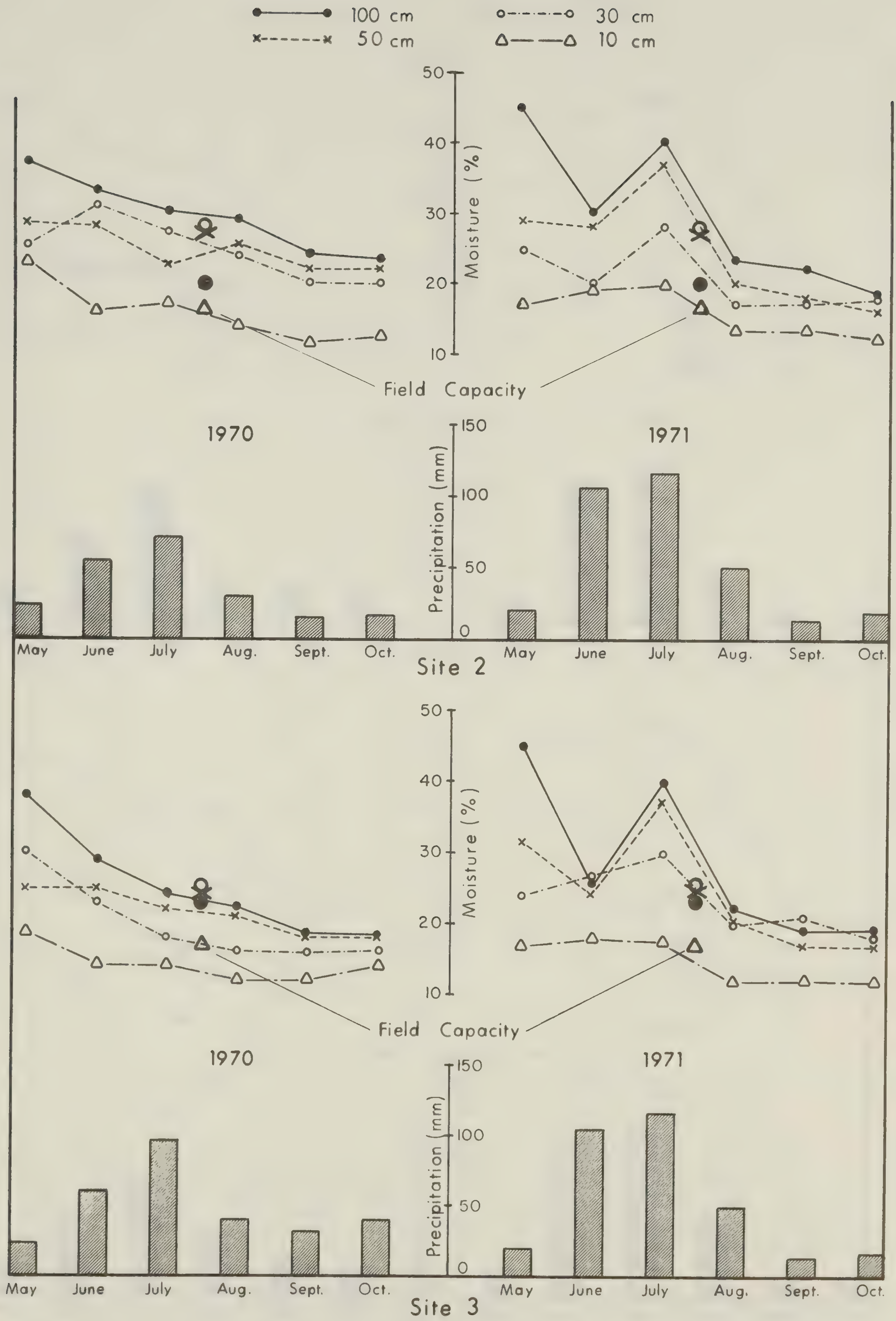


FIGURE 11b—Mean Monthly Moisture Contents and Precipitation at Sites 2 and 3

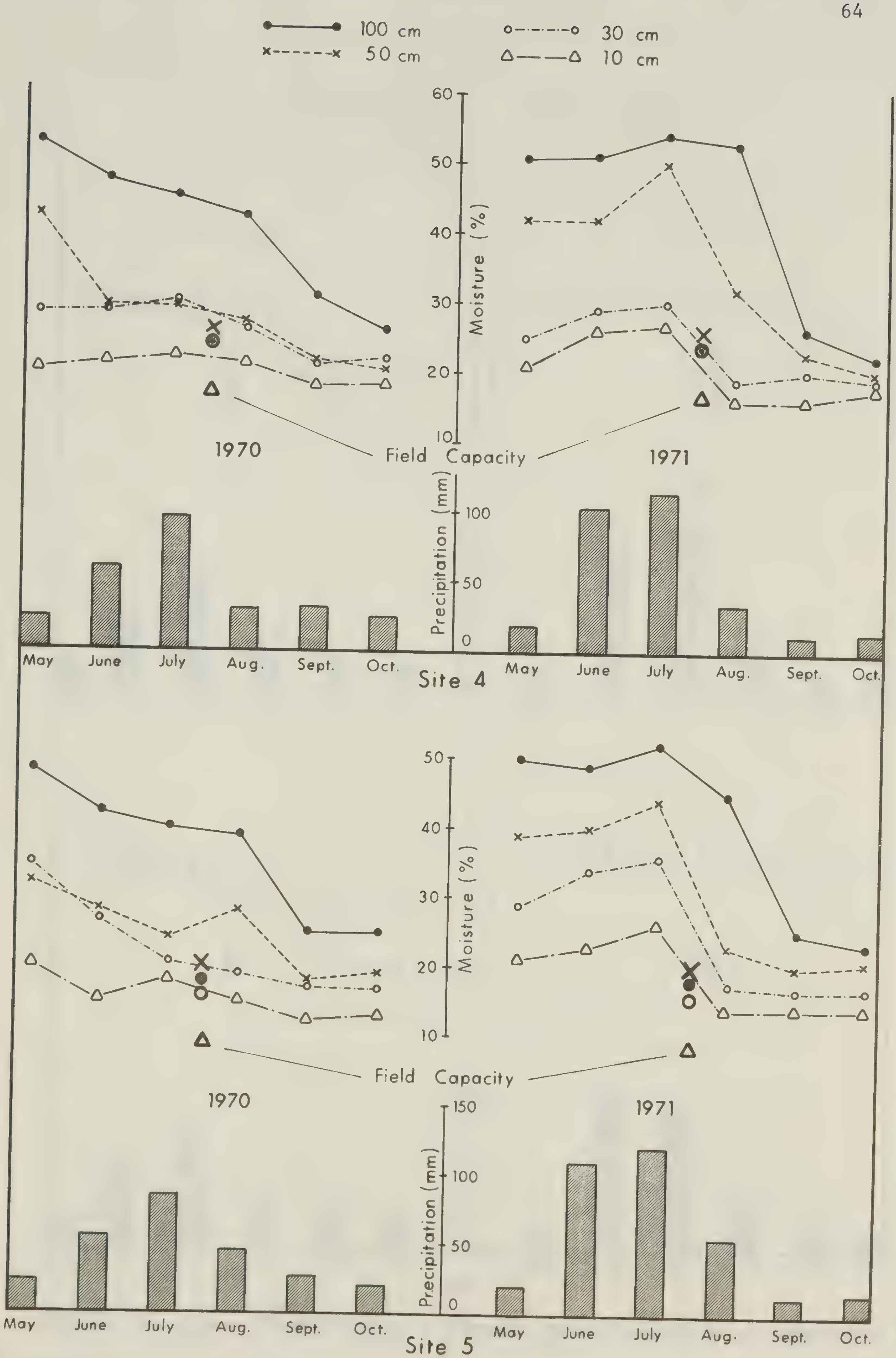


FIGURE 11c — Mean Monthly Moisture Contents and Precipitation at Sites 4 and 5

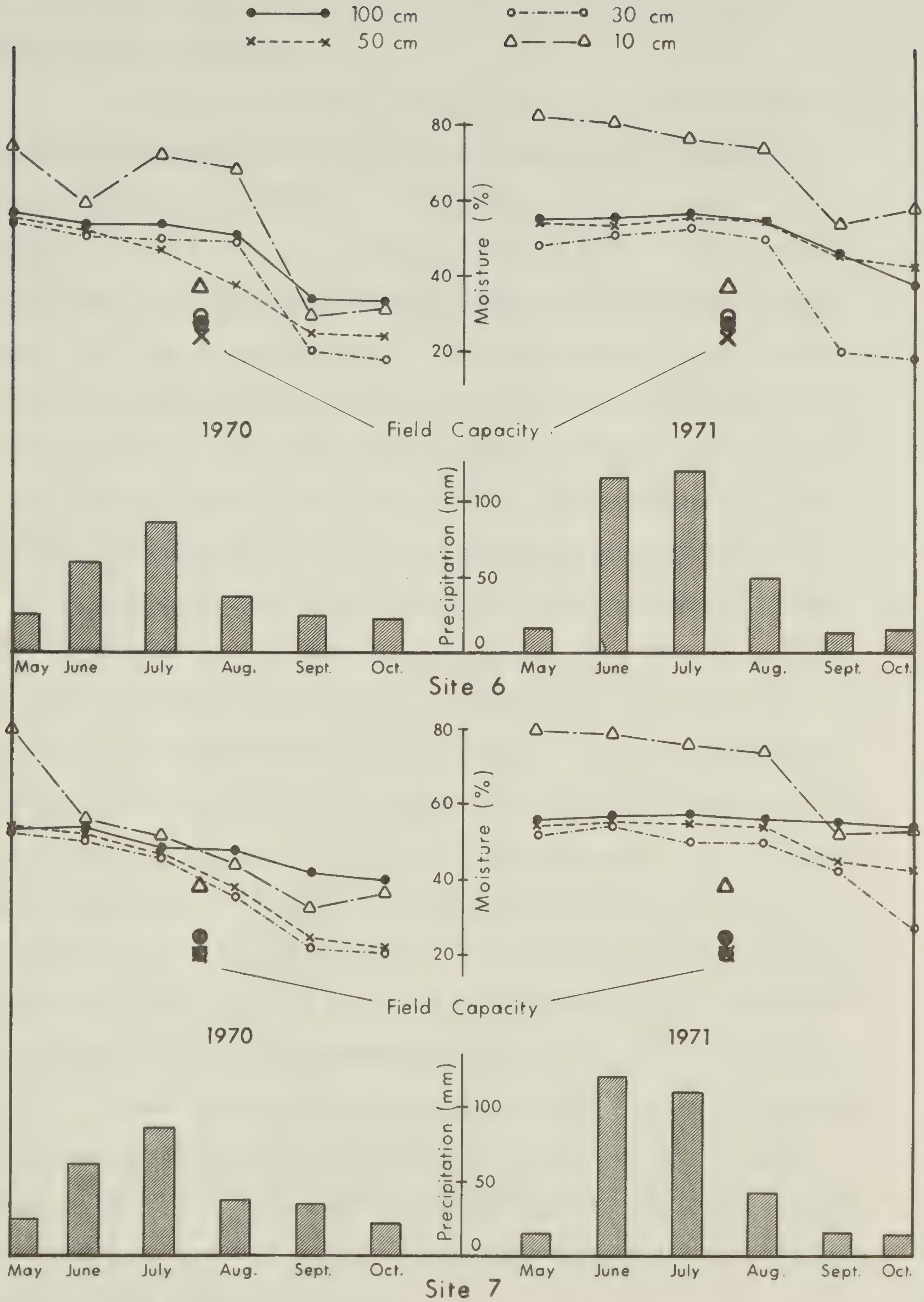


FIGURE 11d—Mean Monthly Moisture Contents and Precipitation at Sites 6 and 7

At all depths at each site, the moisture content did not decrease substantially until August.

The depth to the water table in a soil is closely related to precipitation, evapotranspiration, and position in the landscape. Figure 12 depicts the fluctuation of the water table from May to October at sites 4, 5, 6, and 7 during 1970 and 1971. At sites 6 and 7, the water table persisted near the surface until the first week of August, 1971 then dropped rapidly. The depth to water table reflected the greater amounts of precipitation which occurred in June and July of 1971 as compared to the same months in 1970. The water table at sites 4 and 5 did not appear at the surface at any time during the two years but the lower portion of the solum was saturated until early in July.

The moisture status of a soil influences temperature regime. Moist soils warm and cool more slowly than dry soils (Shul'gin,1957). The cold nature of wet soils can be attributed to their high heat capacities. The specific heat of any substance can be defined as the calories of heat required to raise one gram one degree centigrade. The heat capacity of water is about four times greater than that of several soil constituents. Therefore, as the moisture content of a soil increases so does its heat capacity. This explains the cooler soil temperatures that prevailed at site 7 in comparison to the temperatures at the other sites on the south-facing slope.

Aspect had an influence on soil moisture regime. The moisture content was generally higher at the various positions on the north-facing slope than at corresponding positions on the south-facing slope. This difference could be explained by greater evaporation from the soil surface on the southern exposure.

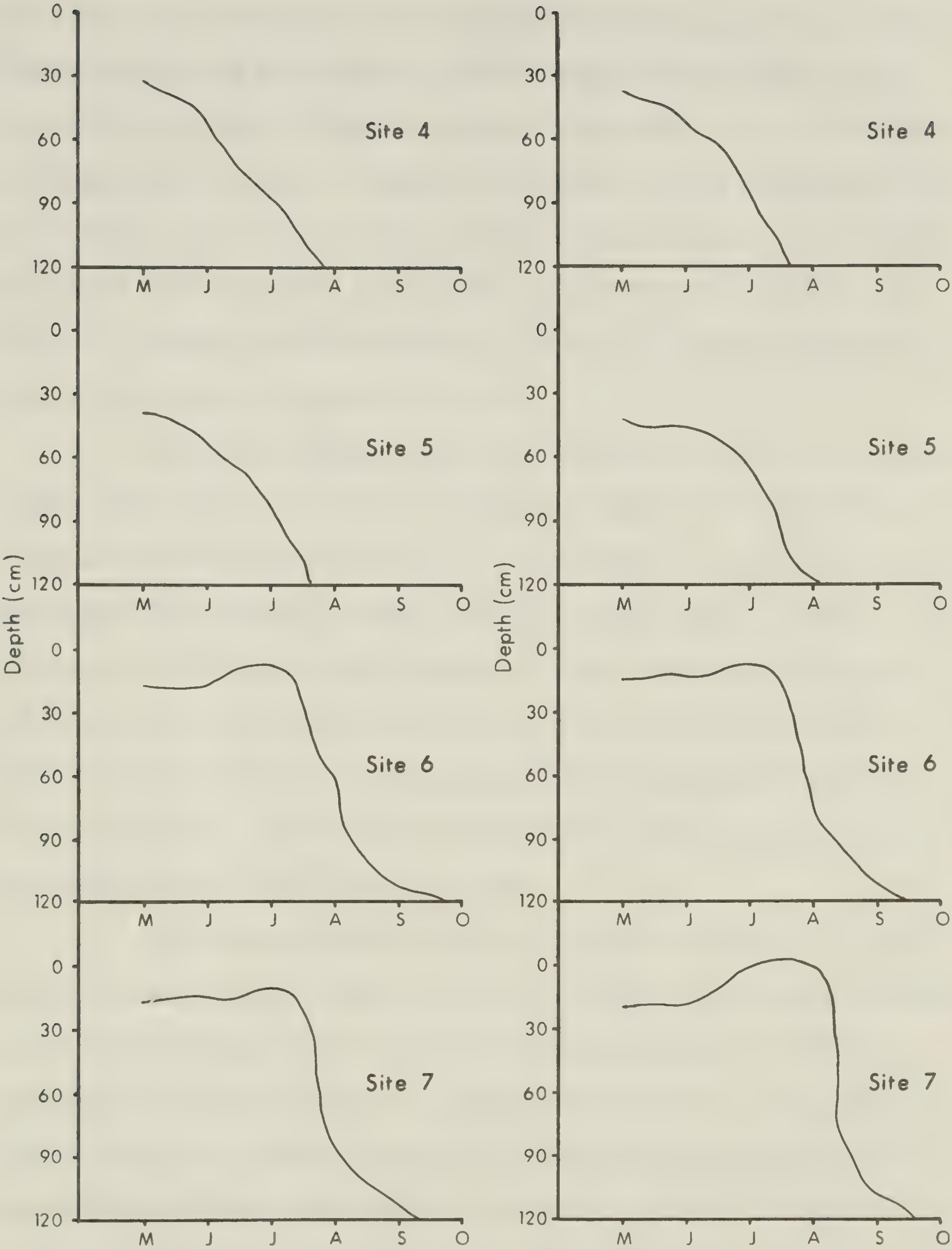


FIGURE 12 — Water Table Levels at Sites 4,5,6 and 7 in 1970 and 1971

The amount of moisture available to plants is represented by the difference between the field capacity and wilting point of a soil. Field capacity can be considered as the amount of water held in the soil after the rate of downward movement has ceased. The wilting point is that moisture content at which a soil cannot supply sufficient water to maintain plant turgor resulting in permanent wilting. The moisture constants for wilting point and field capacity for the soils in this study are presented in the appendix. The field capacity moisture levels are also included in Figures 11a to 11d.

These data indicate that the soil moisture did not go as low as the wilting point at any time during the time of the study. The soils at the 10 cm depth at sites 1, 2, and 3 had a moisture content below the field capacity for most of the growing season in 1970. However, in 1971 the moisture content in these same soils reflected the relatively dry month of May and then the significantly wetter months of June and July as indicated by the precipitation totals. At the 10 cm depth at sites 6 and 7 the moisture content remained above the field capacity level until September.

The moisture content at the 30 cm depth at sites 1, 2, and 3 showed trends similar to those at the 10 cm depth. The moisture content was below field capacity for most of the growing season in 1970 and reflected the larger amounts of precipitation in 1971. At the 100 cm depth at these three sites the moisture content dropped below field capacity in September and October. At the 100 cm depth at sites 4, 5, 6, and 7 the moisture content persisted above the field capacity level throughout the growing season.

4. Oxidation-Reduction Potentials

A knowledge of the oxidation-reduction potential in soils has been used to explain soil formation phenomena. Jackson (1956) defines the oxidation potential of a chemical system " as a measure of the tendency for oxidation reactions to occur in that system". Quispel (1947) states that " the redox potential of a soil is determined by the antagonistic influence of reducing substances and oxygen".

Several investigators have studied the factors influencing the redox potential of soils. Quispel (1947) noted that the oxidation-reduction level of waterlogged soils was mainly determined by the aeration of the soil as affected by water content and structure of the soil. However, Burrows and Cordon (1936) reported that moisture content had a negligible effect on redox potential. Similarly, Heintze (1935) reported that redox potential was no criterion of waterlogging.

Redox potentials greater than 750 mv correspond to fully aerobic conditions (Volobuev, 1963). In general, redox potentials below 200 mv indicate strongly reducing conditions (Volobuev, 1963 and Starkey and Wight, 1945).

Data were gathered at four depths at each of the sites. In general, the data show that redox potentials were lowest in the spring, and increased through the summer and fall. The redox potential remained similar from July and August to October. When moisture content was compared to redox potential, there appeared to be a direct relationship between the two variables. As moisture content decreased the redox potential increased. In other words, one would expect the redox potential to be lower in a soil that is saturated than in the same soil at field capacity. At field capacity air has replaced water in most of

the macropores while the micropores are still filled with water. If the actual moisture content of a soil at any given time is compared to the field capacity moisture level for that soil, an estimate of the drainage status of the soil can be made. A ratio expressed in percent can be derived by dividing the actual moisture content for that soil by the field capacity moisture level for that same soil. A ratio of 100 or greater indicates that the soil is not freely drained. Figures 13a to 13d represent a comparison of this ratio to the redox potential of the soils. The moisture and redox values for individual depths at sites 1,2, and 3 were grouped. A similar grouping was made of the moisture and redox values for sites 4 and 5 and for 6 and 7. The figures show no major differences between the 1970 and 1971 seasons.

The redox potentials were highest at the 10 cm depths of the well drained positions. These horizons were also characterized by relatively low moisture contents and were well below the field capacity moisture level for most of the six month period. Of all sites, the widest variations in moisture content and redox potential were observed at the various depths at sites 4 and 5. The profiles that did have the wider range of fluctuations in moisture content and redox potential appear to be the most strongly developed morphologically. The soils at the depressional sites are less strongly developed and were characterized by narrower fluctuations in moisture content and redox potential. From a study of three clay soils, McKeague (1965) concluded that the soil which was subject to the widest fluctuations in water table, in wetness and dryness, and in oxidation-reduction staus, was the most strongly developed.

Burrows and Gordon (1936) observed that organic matter tends

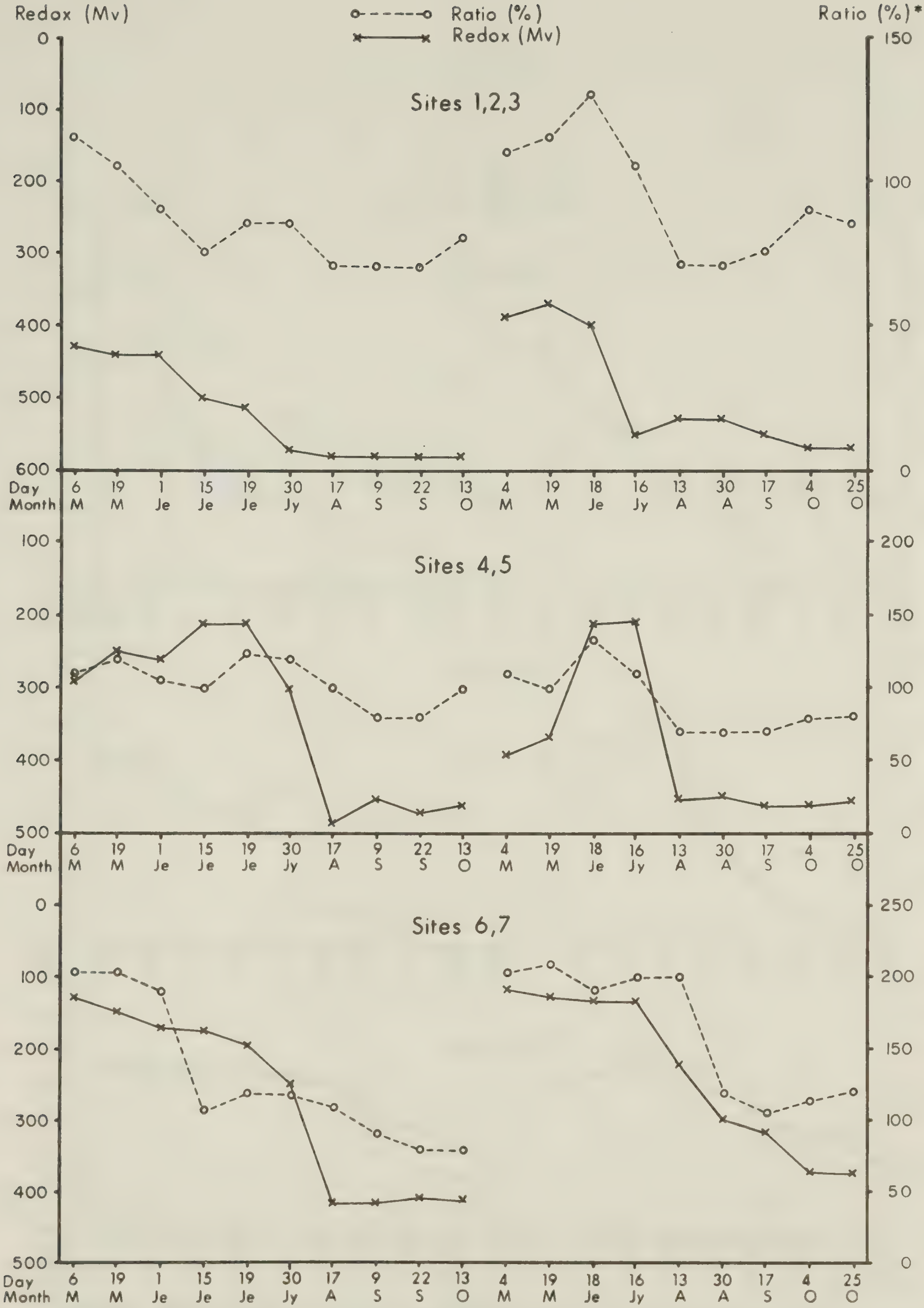


FIGURE 13 a — Redox Potential and Moisture Status of the Soils at 10 cm Depth

$$\text{*Ratio (\%)} = \frac{\text{Actual Moisture}}{\text{Field Capacity}}$$

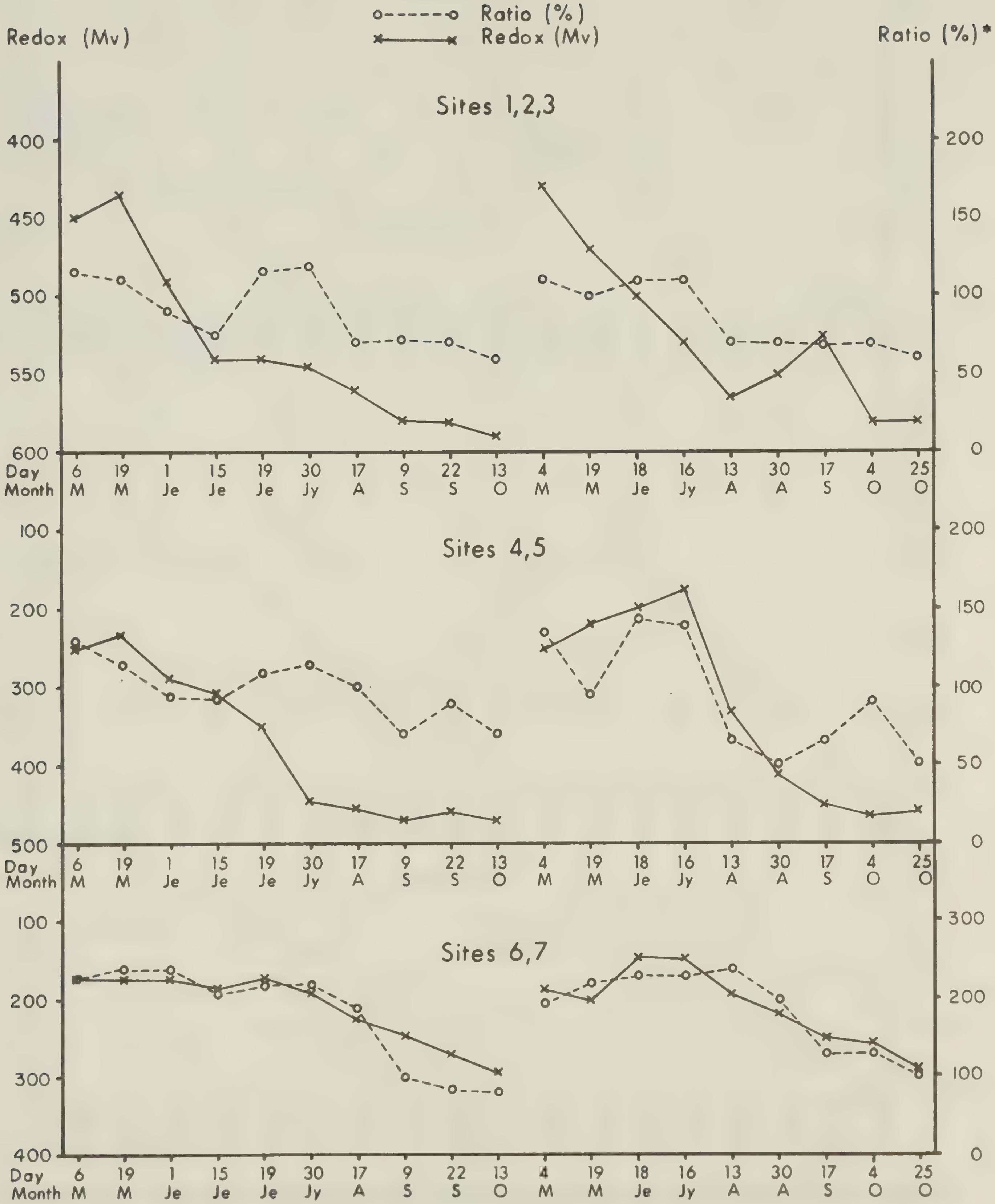


FIGURE 13 b — Redox Potential and Moisture Status of the Soils at 30 cm Depth

$$*\text{Ratio (\%)} = \frac{\text{Actual Moisture}}{\text{Field Capacity}}$$

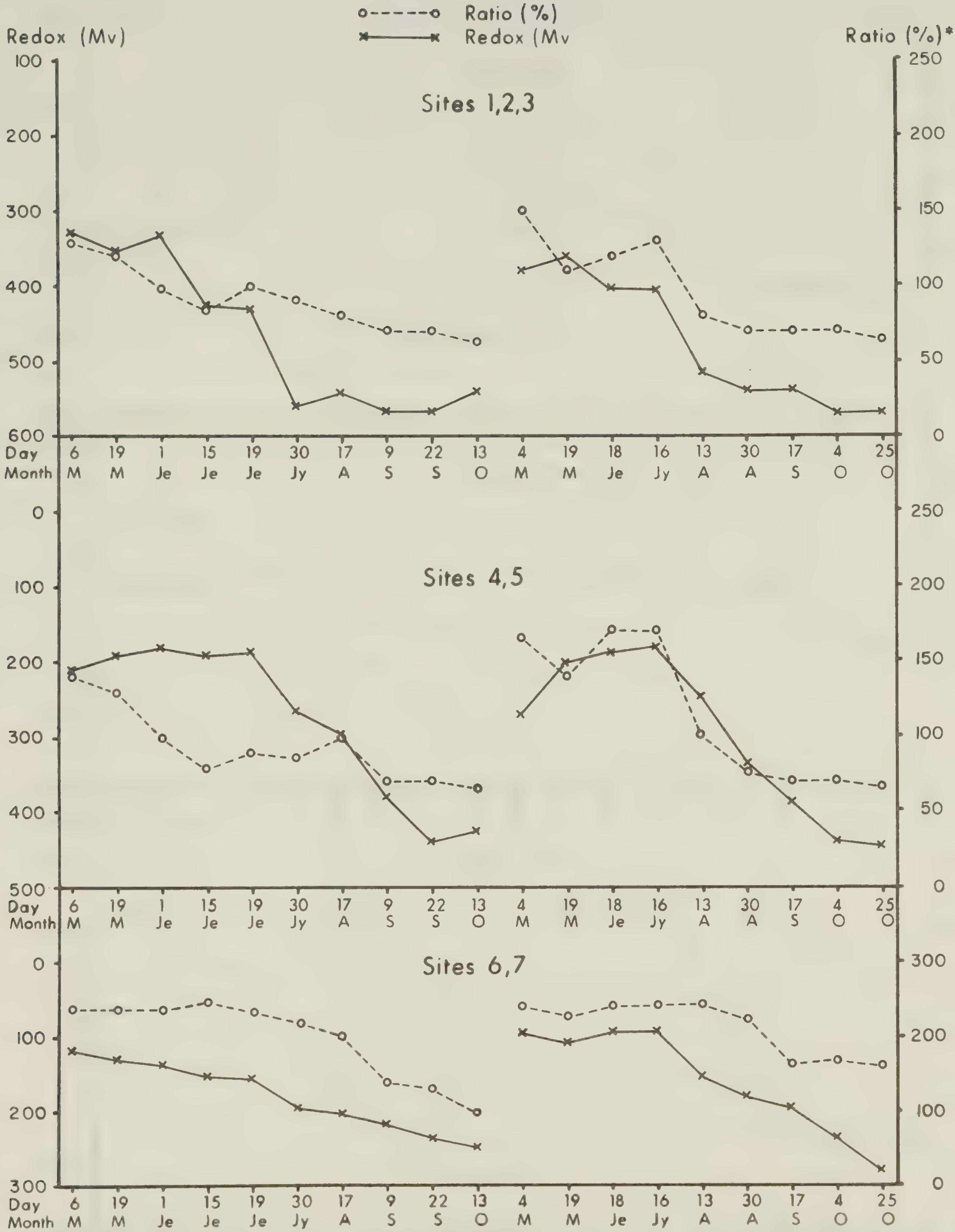


FIGURE 13c — Redox Potential and Moisture Status of the Soils at 50 cm Depth

$$*\text{Ratio } (\%) = \frac{\text{Actual Moisture}}{\text{Field Capacity}}$$

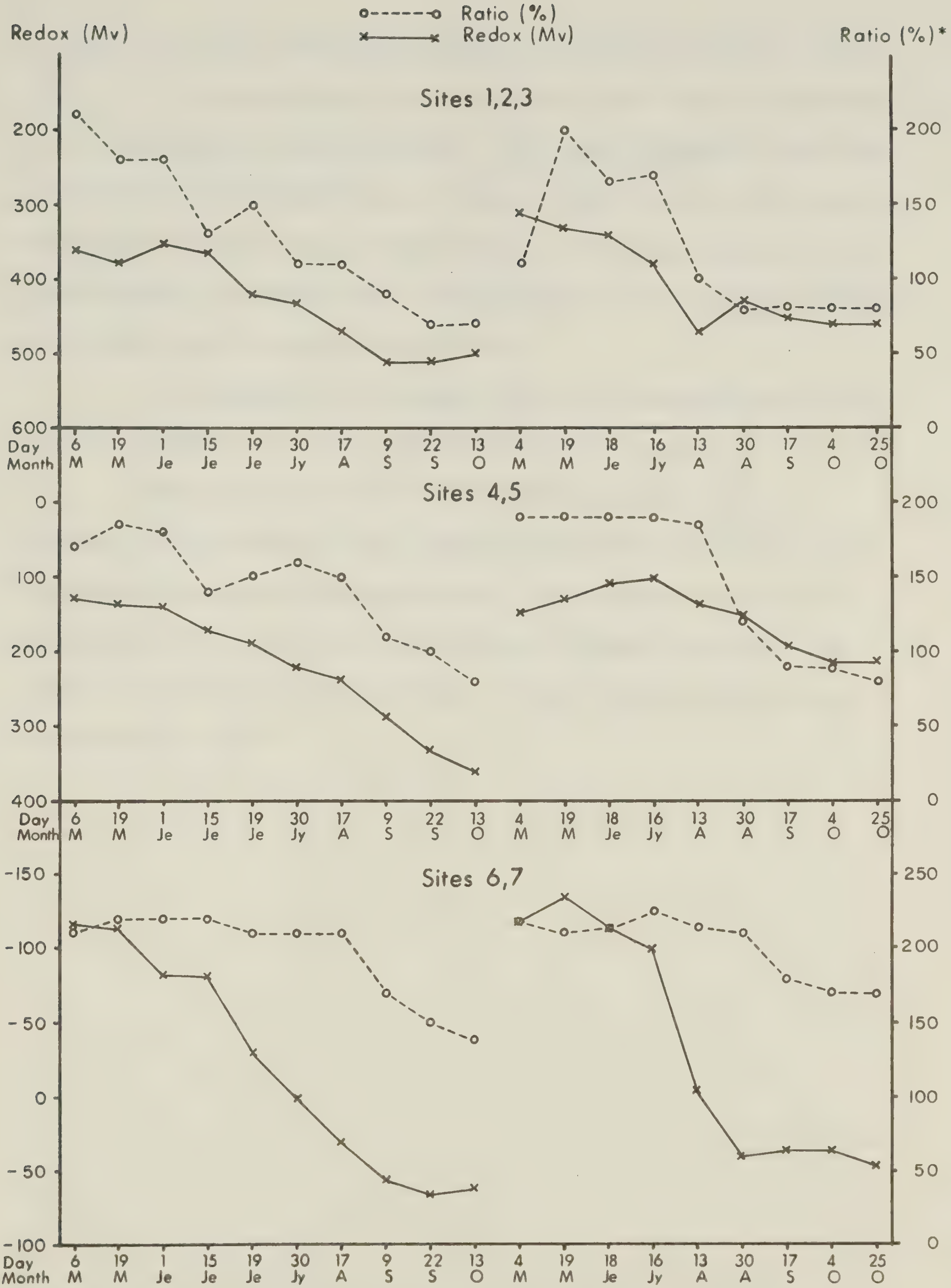


FIGURE 13 d — Redox Potential and Moisture Status of the Soils at 100 cm Depth

$$*\text{Ratio (\%)} = \frac{\text{Actual Moisture}}{\text{Field Capacity}}$$

to lower the redox potential of the soil. At the 10 cm depth at sites 6 and 7, the redox potential was considerably lower than the potential at the same depth at the other sites. This lower potential could have resulted partly from the effect of organic matter content. In addition, the moisture content was also much higher at the 10 cm depth at sites 6 and 7 than at the other sites. This higher moisture content persisted for a large part of the six month period.

The percentage of dissolved oxygen has a significant effect on redox potential but was not determined in this study.

The moisture and redox data explain the occurrence of Gleysolic soils at sites 6 and 7 and Gleyed Luvisols at sites 4 and 5. The Gleysolic soils are characterized by thick organic layers, dull, drab colors in the solum and less strongly developed structure than those in the better drained positions. These features reflect their high moisture status.

VI. SUMMARY AND CONCLUSIONS

This study of seven soil pedons in a deciduous forest area was undertaken to determine the influence of relief and microclimate on certain soil properties. Three sites were located on each of the north- and south-facing slopes and one site was located in the crown position of a moderately rolling till knob.

The vegetation of the study area was characterized and some chemical, physical, and mineralogical analyses were conducted on the soils. Emphasis was placed on the monitoring of the moisture and temperature regimes at four different depths. Seasonal variations in pH and redox potential were measured.

The pattern and composition of the vegetation of the two aspects showed some variation. Few species were found to be absolutely exclusive to either slope; rather, differences were found in relative density and occurrence of species.

Thickness of horizons and particle size distribution indicated that a slightly greater amount of leaching occurred in the soils on the north-facing slope than in the soils on the south-facing slope. Also, more leaching was evident in the soils which occurred in the lower slope positions than in the upper slope positions. Percentages of total extractable iron and aluminum were similar for six of the seven sites. The various soils showed no apparent differences in cation exchange capacity. X-ray diffraction data indicated that the clay mineral composition in the seven pedons was similar with minor differences in distribution occurring among the various horizons.

The seasonal variation in soil pH was similar at the seven

sites. Moisture and temperature data were collected at the 10, 30, 50, and 100 cm depths at each of the sites during the months of May to October in 1970 and 1971. Maximum soil temperature at all depths at each site was reached during the month of August. Soil temperatures were generally higher at the sites on the south-facing slope than at corresponding sites on the north-facing slope. Throughout the growing season air temperature was usually higher than the soil temperature at the 10 cm depth.

The moisture regime of the soils varied with position on the slope. The soil moisture content at the 10 cm depth at sites 1, 2, and 3 was below the field capacity level for most of the growing season. Soil moisture percentage remained above the wilting point during the period of data collection. The precipitation patterns during the two years were reflected by the moisture content of the soils. Soil moisture content was generally lower at the sites on the south-facing slope than at sites on the north-facing slope.

Redox potential varied seasonally. It was lowest in the spring when the moisture content was high. As the moisture content decreased and aeration increased, the redox potential increased.

In conclusion, the data indicate that certain properties of a soil are influenced by its position in the landscape and by microclimatic features.

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APPENDIX

TABLE AIa - Some Chemical Data for Certain Horizons at Each Site

Site 1	%N	%C	C/N Ratio	$CaCO_3$ Equiv. %
L-H	0.77	-	-	-
Ae	0.05	0.47	9	-
AB	0.05	0.46	9	-
Bt_1	0.04	0.55	14	-
Bt_2	0.04	0.59	15	-
BC	-	-	-	-
Ck	-	-	-	4.1
Site 3				
L-H	0.76	-	-	-
Ae	0.05	0.40	8	-
AB	0.06	0.60	10	-
Bt	0.05	0.59	12	-
BC	-	-	-	-
Ck	-	-	-	3.2
Site 5				
L-H	1.44	-	-	-
Ae	0.07	0.85	12	-
AB	0.06	0.61	10	-
Btgj	0.06	0.60	10	-
BCg	-	-	-	-
Ckg	-	-	-	10.2
Site 7				
L-H	2.34	-	-	-
Ah	0.48	5.95	12	-
Aeg	0.03	0.43	14	-
Btg_1	0.05	0.56	11	-

Site 2	%N	%C	C/N Ratio	$CaCO_3$ Equiv. %
L-H	1.09	-	-	-
Ae	0.05	0.48	10	-
AB	0.06	0.54	9	-
Bt_1	0.05	0.59	12	-
Bt_2	0.04	0.68	17	-
BC	-	-	-	-
Ck	-	-	-	5.2
Site 4				
L-H	1.62	-	-	-
Ae	0.06	0.54	9	-
AB	0.04	0.40	10	-
$Btgj_1$	0.04	0.55	14	-
$Btgj_2$	0.03	0.50	17	-
BCg	-	-	-	-
Ckg	-	-	-	5.2
Site 6				
L-H	1.46	-	-	-
Ah	0.46	4.9	11	-
Aeg	0.05	0.48	10	-
Btg	0.04	0.20	5	-
BCg	-	-	-	-
Ckg	-	-	-	6.5
Site 7				
Btg_2	0.05	0.54	11	-
BCg	-	-	-	-
Ckg	-	-	-	9.8

TABLE AIb - Oxalate- and Dithionite-Extractable Iron and Aluminum

		Dithionite			Oxalate		
Horizon	Site	%Al	%Fe	%Fe+Al	%Al	%Fe	%Fe+Al
Ae	1	0.07	0.41	0.48	0.07	0.08	0.15
Ae	2	0.02	0.56	0.58	0.09	0.11	0.20
Ae	3	0.06	0.41	0.47	0.07	0.14	0.21
Ae	4	0.06	0.51	0.57	0.14	0.19	0.33
Ae	5	0.06	0.43	0.49	0.04	0.12	0.16
Ah	6	0.10	0.40	0.50	0.03	0.25	0.28
Ah	7	0.13	0.41	0.54	0.03	0.33	0.36
AB	1	0.14	0.86	1.00	0.06	0.12	0.18
AB	2	0.10	0.83	0.93	0.21	0.14	0.35
AB	3	0.10	0.80	0.90	0.14	0.21	0.35
AB	4	0.08	0.70	0.78	0.18	0.18	0.36
AB	5	0.09	1.05	1.14	0.14	0.15	0.29
Bt	1	0.11	1.13	1.24	0.09	0.19	0.28
Bt	2	0.10	1.13	1.23	0.14	0.23	0.37
Bt	3	0.11	1.00	1.11	0.13	0.19	0.32
Btgj	4	0.11	1.00	1.11	0.14	0.34	0.48
Btgj	5	0.09	1.05	1.14	0.14	0.15	0.29
Btg	6	0.08	0.94	1.02	0.16	0.33	0.49
Btg	7	0.03	1.65	1.68	0.10	0.99	1.09
BC	1	0.09	0.94	1.03	0.07	0.21	0.28
BC	2	0.07	0.98	1.05	0.14	0.17	0.31
BC	3	0.09	1.13	1.22	0.08	0.14	0.22
BCg	4	0.06	0.99	1.05	0.06	0.20	0.26
BCg	5	0.05	1.28	1.33	0.10	0.21	0.31
BCg	6	0.07	1.23	1.30	0.13	0.25	0.38
BCg	7	0.05	1.19	1.24	0.08	0.51	0.59
Ck	1	0.07	0.96	1.03	0.06	0.15	0.21
Ck	2	0.04	0.93	0.97	0.03	0.25	0.28
Ck	3	0.05	0.99	1.04	0.03	0.12	0.15
Ckg	4	0.03	0.86	0.89	0.06	0.18	0.24
Ckg	5	0.07	0.70	0.77	0.07	0.13	0.20
Ckg	6	0.05	0.91	0.96	0.10	0.22	0.32
Ckg	7	0.09	0.85	0.94	0.09	0.34	0.43

TABLE AIIa - Daily Soil Temperatures (°C) at Four Depths

Depth	Site	May, 1970 4	6	8	13	15	19	21	25	29
10 cm	1	2.4	3.5	4.2	3.5	6.0	6.0	7.6	8.4	9.4
	2	-2.0	-0.5	-0.5	0.5	4.0	5.0	5.6	7.0	7.5
	3	-1.2	0.3	2.0	0.5	3.3	3.3	6.0	7.2	7.8
	4	-2.0	-1.0	-1.5	-0.5	3.3	4.0	5.3	6.7	6.0
	5	4.0	4.0	6.0	6.0	7.2	7.2	7.8	8.9	9.4
	6	1.0	1.0	2.8	2.8	4.0	4.4	5.0	6.0	6.7
	7	2.6	3.6	4.0	3.6	4.4	5.0	5.6	7.2	7.2
30 cm	1	-1.0	0.5	1.0	1.0	4.0	4.0	4.4	5.0	5.6
	2	0.0	0.5	0.3	2.4	3.3	5.0	5.0	5.8	6.0
	3	-1.0	0.5	1.0	2.4	4.0	5.0	5.8	7.0	7.2
	4	-1.7	-0.7	-0.5	1.0	3.6	5.6	5.6	6.7	6.7
	5	1.4	2.6	3.3	2.8	4.2	5.0	6.0	6.3	7.0
	6	0.0	0.5	1.0	0.5	1.7	2.8	4.0	4.0	4.2
	7	0.5	1.7	2.4	1.7	2.4	3.3	5.0	5.0	5.0
50 cm	1	-0.2	1.0	0.5	2.4	3.6	3.6	4.2	5.6	5.6
	2	-4.0	-3.3	-4.4	-1.5	-1.0	-1.5	2.4	3.3	4.0
	3	0.0	0.0	1.7	3.0	3.3	4.4	5.0	6.0	6.7
	4	-4.0	-4.4	-3.3	-2.0	0.0	2.4	2.4	4.0	4.0
	5	-0.3	-0.7	0.0	0.5	1.0	2.4	2.8	5.6	4.4
	6	-0.2	-1.0	-0.5	-1.0	-0.5	0.0	0.0	1.7	1.0
	7	0.8	1.4	0.0	-0.5	0.0	0.0	0.5	2.8	2.4
100 cm	1	0.0	-0.2	-0.7	2.4	3.6	3.6	4.0	5.6	5.6
	2	-0.2	0.3	-1.2	-0.2	0.3	1.4	1.4	2.8	3.0
	3	2.8	1.7	1.0	2.8	2.8	3.0	3.6	4.0	5.3
	4	-0.5	-0.5	-1.5	1.0	1.0	2.0	2.6	3.0	4.4
	5	-1.2	-1.2	-0.2	0.0	0.0	1.0	1.7	2.0	2.6
	6	-0.5	-0.5	-0.5	-1.0	-0.5	0.0	0.0	0.5	0.5
	7	0.5	0.5	1.0	1.0	1.0	1.7	2.4	2.8	2.8

TABLE AIIb - Daily Soil Temperatures (°C) at Four Depths

Depth	Site	June, 1970 1	5	8	12	15	18	22	26
10 cm	1	10.0	13.6	12.0	13.3	12.8	14.0	14.0	16.0
	2	8.3	12.0	10.8	12.2	12.0	13.7	13.7	14.2
	3	8.3	11.7	11.0	12.8	12.5	14.0	14.4	14.4
	4	7.6	10.8	10.0	9.4	10.8	12.0	12.6	12.8
	5	10.0	13.3	11.7	12.8	14.0	14.0	15.6	14.4
	6	10.0	11.7	12.2	11.0	12.2	11.7	14.4	15.0
	7	11.0	13.0	13.7	12.2	13.3	13.3	15.6	15.0
30 cm	1	6.0	8.9	8.9	8.3	9.4	10.0	11.7	11.7
	2	7.0	8.9	9.4	8.9	9.7	10.6	10.8	11.0
	3	8.3	10.0	10.0	9.7	9.4	11.0	11.0	12.0
	4	7.0	8.6	9.4	8.6	9.4	10.6	12.2	12.2
	5	7.2	9.7	9.2	9.5	9.4	10.0	11.0	12.0
	6	4.4	6.0	6.3	7.8	9.2	8.9	11.0	11.0
	7	5.6	7.2	7.2	8.9	9.7	10.6	12.2	12.2
50 cm	1	6.0	8.0	8.6	7.5	8.6	9.4	10.6	10.6
	2	4.4	6.7	7.8	7.8	7.8	8.9	9.4	10.0
	3	7.0	8.0	8.9	8.6	8.6	9.7	10.0	10.6
	4	5.0	7.2	7.8	7.2	8.3	8.9	9.4	10.0
	5	5.6	8.3	7.8	7.2	7.8	8.9	10.0	10.6
	6	1.7	4.0	4.4	5.0	5.6	8.3	9.4	9.7
	7	2.8	5.6	5.6	6.0	7.2	9.4	10.0	10.3
100 cm	1	4.4	5.6	5.6	5.8	8.6	9.4	10.6	10.6
	2	3.6	4.4	5.3	5.0	5.8	6.5	7.2	7.8
	3	5.3	6.3	6.7	7.2	7.2	7.2	7.8	8.3
	4	4.0	5.0	5.6	6.3	6.3	7.5	6.3	7.5
	5	3.6	4.2	4.4	5.6	5.6	5.8	7.8	6.3
	6	1.0	1.7	2.4	4.4	5.6	4.4	5.0	5.6
	7	3.3	4.2	4.2	4.4	5.0	5.6	5.6	6.3

TABLE AIIc - Daily Soil Temperatures (°C) at Four Depths

		July, 1970					
Depth	Site	3	10	17	20	24	30
10 cm	1	16.0	17.2	16.0	15.3	15.0	14.0
	2	13.7	16.0	15.3	14.4	14.7	12.8
	3	13.3	15.0	15.0	16.7	15.0	12.8
	4	12.6	14.4	16.7	14.4	14.4	12.6
	5	15.0	15.6	15.0	15.6	15.6	14.0
	6	16.0	16.0	15.6	15.0	15.0	12.8
	7	16.4	17.0	15.8	15.6	15.6	14.4
30 cm	1	11.0	13.3	14.4	14.4	14.4	11.7
	2	10.0	12.2	13.3	12.8	12.5	11.4
	3	12.0	14.0	15.3	15.3	14.2	12.5
	4	11.0	12.5	12.2	12.5	13.3	11.7
	5	11.0	13.3	15.6	13.7	12.8	12.0
	6	7.8	11.0	9.4	11.0	11.0	10.3
	7	10.0	12.0	11.0	12.0	12.5	12.5
50 cm	1	10.6	12.0	12.5	12.0	11.7	11.4
	2	10.6	12.2	13.3	12.2	15.0	11.7
	3	10.6	11.7	11.4	12.2	11.7	11.0
	4	10.0	12.2	12.2	12.2	12.2	11.0
	5	8.9	12.2	12.8	14.2	12.2	11.7
	6	5.8	10.8	11.0	11.0	11.0	10.3
	7	6.7	12.5	12.0	11.4	11.7	11.4
100 cm	1	7.8	9.2	10.3	9.2	13.7	10.3
	2	8.3	8.6	9.7	11.0	9.7	10.6
	3	7.8	10.0	10.8	10.8	10.6	10.8
	4	7.5	9.4	10.0	12.2	10.0	10.3
	5	7.2	8.3	11.0	10.8	9.4	9.2
	6	6.7	7.2	9.7	8.0	8.6	7.8
	7	6.0	9.4	10.8	10.8	10.3	10.0

TABLE AIId - Daily Soil Temperatures (°C) at Four Depths

Depth	Site	August, 1970 4	7	10	14	17	21	24	26
10 cm	1	17.2	20.0	14.5	14.5	12.8	17.7	17.2	15.6
	2	15.3	18.4	14.7	14.4	12.2	15.3	15.3	13.3
	3	15.0	17.7	15.0	14.0	12.2	14.4	15.0	13.3
	4	15.0	17.2	13.3	13.3	12.0	14.0	14.0	12.0
	5	15.0	18.0	14.4	14.4	13.0	16.0	16.5	14.4
	6	15.6	17.7	14.0	13.3	11.7	14.0	14.0	11.7
	7	15.6	17.7	15.0	14.4	11.0	12.5	12.8	12.5
30 cm	1	16.7	15.0	14.0	13.3	12.8	12.2	13.3	11.0
	2	12.8	14.0	12.8	12.5	12.0	12.0	12.5	12.0
	3	14.4	15.8	14.7	14.0	13.3	13.3	14.0	13.3
	4	13.3	14.2	13.0	12.5	12.2	12.2	12.5	12.2
	5	13.3	14.4	13.7	13.3	13.3	12.8	13.3	12.8
	6	10.6	11.7	11.0	12.0	11.0	10.0	11.0	11.0
	7	12.8	14.4	14.0	12.8	12.2	12.8	12.8	12.8
50 cm	1	12.5	13.3	13.0	13.0	12.5	12.0	12.5	12.8
	2	13.3	14.4	13.3	13.3	12.8	12.2	12.2	12.2
	3	12.5	12.8	12.5	12.5	12.0	11.0	11.7	11.7
	4	12.8	13.3	12.8	12.8	12.2	12.2	12.2	12.2
	5	12.8	14.4	13.3	12.8	12.8	11.7	12.8	12.2
	6	11.0	13.3	12.2	11.7	11.0	10.3	11.0	11.0
	7	12.0	9.4	14.0	12.8	12.2	10.8	11.7	11.0
100 cm	1	10.8	11.0	11.0	11.0	11.0	11.0	11.0	10.6
	2	10.6	11.0	11.0	11.0	11.0	11.0	11.0	11.0
	3	11.0	11.0	11.7	11.7	11.7	11.0	11.0	11.0
	4	10.8	11.4	12.2	12.0	11.4	11.4	11.4	11.4
	5	9.7	10.3	10.3	10.8	10.3	10.3	10.3	10.3
	6	8.6	9.4	9.7	9.7	9.7	10.0	10.0	10.0
	7	10.8	10.0	11.4	10.8	10.3	10.8	10.8	10.8

TABLE AIIe - Daily Soil Temperatures (°C) at Four Depths

Depth	Site	September, 1970					October, 1970			
		11	17	22	25	29	1	13	15	21
10 cm	1	6.4	9.0	9.4	6.0	12.0	11.4	4.0	4.0	4.2
	2	5.0	9.4	8.9	4.0	11.4	10.8	3.6	3.0	4.0
	3	5.6	7.2	8.3	5.0	10.0	8.9	3.3	2.8	3.3
	4	5.6	7.6	8.0	4.2	10.0	8.6	2.8	2.4	2.8
	5	7.6	10.0	10.0	6.7	12.0	11.0	6.0	4.4	7.0
	6	5.6	8.3	8.0	4.4	10.0	10.0	3.3	4.0	5.0
	7	6.0	7.8	8.6	5.0	10.0	10.6	4.0	4.4	7.5
30 cm	1	8.3	7.8	8.3	4.0	8.9	8.3	4.0	4.0	4.4
	2	8.6	8.6	8.0	7.2	8.6	8.9	5.6	5.0	5.6
	3	9.2	8.6	9.2	7.0	9.7	9.7	5.0	5.0	5.6
	4	8.6	8.6	8.6	6.7	8.6	8.6	5.6	5.0	5.6
	5	8.6	7.8	9.2	7.2	9.2	9.2	6.3	4.0	7.2
	6	8.3	8.0	7.8	6.0	8.3	9.4	7.8	4.4	4.4
	7	9.2	9.2	8.0	7.0	9.2	8.0	6.0	5.6	5.6
50 cm	1	9.2	7.0	7.5	7.0	8.0	8.6	5.0	4.7	5.6
	2	9.4	8.3	8.3	7.8	8.3	8.3	5.6	5.0	5.0
	3	9.7	7.8	8.0	7.2	8.3	8.0	6.0	5.0	5.0
	4	8.3	7.2	7.8	5.6	7.2	7.8	3.3	3.3	3.3
	5	8.9	6.0	8.3	6.7	8.3	8.3	5.6	3.3	6.0
	6	7.8	6.0	7.8	6.7	7.2	6.7	5.0	4.2	4.2
	7	9.2	7.2	10.8	7.2	7.2	7.2	5.6	4.7	5.3
100 cm	1	10.3	8.9	8.3	7.0	8.3	8.3	7.0	7.0	6.3
	2	10.0	9.2	9.2	8.3	8.6	8.3	7.2	7.8	7.2
	3	10.8	8.6	9.2	8.6	9.2	9.2	8.3	7.8	7.5
	4	10.3	9.4	9.4	8.9	9.4	8.9	7.7	7.5	7.5
	5	8.9	7.2	7.8	7.2	7.8	8.3	7.0	5.6	7.8
	6	10.0	7.2	8.3	6.7	7.2	7.2	6.3	5.6	6.7
	7	10.6	8.9	8.9	7.0	9.4	9.4	7.0	6.3	7.2

TABLE AIIf - Daily Soil Temperatures (°C) at Four Depths

		May, 1971							
Depth	Site	4	10	13	17	19	21	28	31
10 cm	1	7.0	7.0	9.4	7.0	7.8	7.0	10.3	10.0
	2	5.6	8.9	8.0	6.0	7.5	7.0	8.3	10.0
	3	6.0	9.4	8.9	6.7	9.4	7.8	8.9	11.0
	4	4.7	4.7	7.5	5.3	6.0	6.0	7.8	8.6
	5	7.0	6.7	9.2	7.5	7.5	7.8	9.4	10.0
	6	3.3	4.0	5.6	5.0	5.6	6.0	8.3	8.3
	7	0.0	6.0	6.7	7.2	6.7	6.7	8.9	9.4
30 cm	1	4.0	2.6	5.6	4.4	5.6	5.6	6.7	8.3
	2	4.7	5.8	5.6	5.8	6.7	7.0	7.8	8.6
	3	5.0	5.8	7.2	5.8	7.2	6.3	8.6	9.2
	4	4.4	5.6	7.5	5.8	6.0	6.7	7.5	8.6
	5	7.0	5.0	9.7	7.0	7.8	7.8	12.0	11.0
	6	5.0	3.3	5.6	4.7	5.6	5.6	6.7	7.0
	7	5.6	4.4	7.8	5.0	6.7	6.7	8.3	8.6
50 cm	1	3.6	7.5	6.0	5.0	5.6	5.0	7.0	7.5
	2	0.0	1.7	2.4	2.8	3.3	3.3	4.4	5.6
	3	4.2	5.8	5.8	5.8	6.0	5.8	7.2	7.8
	4	0.5	2.8	4.4	2.8	3.3	4.0	5.6	6.0
	5	1.7	2.8	4.0	4.0	4.0	4.0	5.6	6.7
	6	-1.0	0.0	0.5	0.5	0.5	0.5	4.0	5.8
	7	1.0	1.7	2.4	2.4	2.4	2.4	5.6	6.0
100 cm	1	1.7	3.0	3.0	3.6	4.2	4.2	5.0	5.6
	2	0.8	2.8	2.8	3.0	3.6	3.6	4.4	5.0
	3	2.8	3.6	4.0	4.4	5.0	5.0	5.8	6.7
	4	1.7	2.6	3.0	3.0	4.0	4.0	4.4	5.0
	5	0.5	1.7	2.8	3.6	3.6	3.0	4.2	4.4
	6	-0.5	0.0	0.5	1.0	2.4	2.4	3.6	4.7
	7	0.5	1.0	1.7	2.4	3.3	3.3	4.4	5.0

TABLE AIIg - Daily Soil Temperatures (°C) at Four Depths

		June, 1971						July, 1971			
Depth	Site	4	11	14	18	25	28	2	12	16	22
10 cm	1	12.0	12.2	11.0	9.4	12.0	10.0	12.0	10.8	13.5	16.3
	2	11.4	11.4	10.8	10.0	13.3	11.0	12.0	11.4	14.2	16.0
	3	12.2	11.7	12.2	11.0	13.3	11.0	12.2	12.2	14.4	17.2
	4	10.0	10.6	9.4	9.2	10.6	8.0	10.0	9.4	12.0	14.4
	5	12.2	12.2	11.0	10.0	12.6	14.2	11.7	11.0	15.0	15.0
	6	10.3	10.3	9.4	11.0	10.8	9.2	10.0	10.0	14.2	15.6
	7	11.0	10.6	10.0	11.7	11.7	10.0	10.6	10.5	14.4	16.0
30 cm	1	8.9	9.4	9.4	8.9	10.6	8.3	10.0	9.4	12.2	14.0
	2	9.7	9.7	10.8	9.4	10.6	8.9	9.7	9.7	11.7	11.7
	3	10.0	10.0	10.0	9.7	12.0	9.7	10.6	10.0	13.3	14.4
	4	9.2	8.6	8.6	9.2	10.8	7.8	10.6	9.4	11.7	13.0
	5	12.0	12.2	11.0	9.7	11.0	9.7	10.6	10.6	13.3	15.0
	6	7.5	7.5	8.0	6.7	9.4	8.0	8.6	8.9	10.6	12.2
	7	9.2	9.2	9.7	8.3	10.0	9.7	9.7	10.0	11.7	13.3
50 cm	1	8.0	8.0	8.0	8.0	9.4	8.6	9.4	9.4	11.0	12.2
	2	6.0	7.2	7.8	7.8	8.9	8.3	8.9	8.9	10.0	14.4
	3	8.6	8.6	8.6	8.6	9.4	9.4	8.9	9.4	10.6	11.7
	4	7.8	7.2	10.0	7.8	9.4	3.3	8.9	8.3	10.0	12.2
	5	7.2	7.2	7.2	7.2	9.4	5.6	8.9	8.3	9.4	11.7
	6	6.0	7.0	8.0	6.0	9.2	5.0	7.2	7.8	8.9	9.7
	7	7.2	7.2	8.9	7.2	8.0	7.2	7.8	8.3	9.7	10.6
100 cm	1	5.8	6.3	6.7	7.0	8.3	7.0	7.8	8.3	8.3	9.7
	2	5.3	6.3	7.0	7.2	8.3	7.2	8.3	6.3	9.2	11.7
	3	7.0	7.5	7.2	7.5	8.6	8.6	8.6	9.2	9.2	9.4
	4	6.0	6.3	7.5	7.5	8.0	7.0	8.3	8.9	8.9	10.0
	5	4.4	5.6	6.0	6.7	8.0	8.0	8.0	8.0	8.9	8.9
	6	4.7	4.4	5.6	4.4	5.6	5.6	6.0	7.5	9.2	8.9
	7	5.0	5.6	7.2	7.2	7.2	6.3	8.3	8.9	9.7	9.7

TABLE AIIh - Daily Soil Temperatures (°C) at Four Depths

		August, 1971						
Depth	Site	4	9	13	16	23	27	30
10 cm	1	16.6	16.3	13.7	14.0	13.6	14.7	13.6
	2	16.7	16.0	13.7	13.7	13.7	14.7	13.3
	3	17.8	17.2	15.0	15.0	15.0	15.0	12.8
	4	14.4	14.4	14.0	12.8	12.6	12.8	12.5
	5	16.0	15.6	14.0	14.0	13.0	14.0	13.3
	6	14.2	15.0	12.5	13.3	12.0	13.3	11.7
	7	15.0	15.6	14.0	14.0	12.8	14.0	12.5
30 cm	1	15.0	15.6	16.7	13.3	14.0	12.8	12.8
	2	13.7	13.7	13.7	12.8	13.3	12.2	12.2
	3	15.3	15.8	14.4	14.0	13.3	13.3	13.3
	4	13.3	14.0	13.0	13.0	13.0	12.5	12.5
	5	14.4	15.8	13.3	13.7	13.3	15.6	13.7
	6	12.8	13.0	12.5	11.7	11.7	11.0	12.5
	7	14.0	14.2	13.7	13.0	13.0	13.7	12.0
50 cm	1	13.3	14.0	12.0	12.2	12.5	12.0	12.0
	2	14.0	14.0	14.0	12.8	12.8	12.2	11.7
	3	13.0	12.8	12.2	13.0	12.8	12.8	11.7
	4	14.0	14.0	14.0	12.2	12.2	12.2	11.7
	5	14.0	14.0	14.0	13.3	12.8	12.2	11.7
	6	12.8	12.0	12.5	12.0	10.8	11.7	10.3
	7	14.0	12.0	13.3	12.8	11.4	12.5	10.6
100 cm	1	10.8	11.7	10.3	11.0	11.0	11.0	11.0
	2	12.0	11.7	12.0	11.7	11.7	11.7	11.0
	3	10.8	11.7	11.0	11.7	11.0	11.7	11.0
	4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
	5	9.7	11.4	11.4	11.4	11.4	12.0	10.3
	6	10.8	10.8	10.8	10.8	10.8	10.8	10.0
	7	12.0	12.0	12.0	12.0	12.0	12.0	10.3

TABLE AIIi - Daily Soil Temperatures (°C) at Four Depths

		September, 1971				October, 1971			
Depth	Site	7	10	17	28	4	12	18	25
10 cm	1	11.4	11.5	10.0	6.0	8.3	6.4	3.6	3.6
	2	11.4	12.0	8.9	4.4	8.0	5.0	2.6	2.6
	3	10.0	11.0	8.3	4.4	6.0	5.0	2.4	1.0
	4	9.4	8.6	7.5	4.7	7.2	4.2	2.4	0.2
	5	11.0	11.7	10.6	7.0	8.3	7.5	5.8	5.0
	6	10.0	10.0	8.6	6.0	7.2	4.7	2.8	2.0
	7	11.0	11.0	9.4	8.3	9.4	8.3	7.2	6.0
30 cm	1	11.7	11.7	11.0	6.7	6.7	6.7	3.3	2.8
	2	10.8	9.7	8.9	7.8	7.2	7.2	5.0	4.2
	3	11.7	12.0	9.2	7.8	7.2	7.2	5.0	4.0
	4	10.8	12.2	8.6	7.5	7.5	7.0	5.0	4.0
	5	10.6	11.0	11.4	4.7	7.2	6.3	4.2	3.6
	6	11.7	11.4	10.6	4.2	8.0	8.6	5.8	5.6
	7	11.0	10.6	8.0	8.0	4.2	7.5	6.7	8.9
50 cm	1	11.0	10.6	9.4	7.0	7.5	7.0	4.7	4.2
	2	11.0	11.0	8.9	8.3	7.2	7.2	5.6	3.3
	3	10.8	10.6	9.4	8.0	6.0	7.8	5.8	4.2
	4	11.0	11.0	8.3	7.8	6.0	5.6	3.3	2.7
	5	11.0	11.0	9.4	7.8	6.7	7.2	5.6	4.0
	6	9.7	9.7	8.6	7.2	5.8	6.7	5.0	4.2
	7	10.0	10.0	8.6	7.5	6.7	7.2	6.0	5.3
100 cm	1	8.3	10.3	9.7	8.3	7.8	7.8	7.2	5.8
	2	10.6	12.0	9.7	9.7	8.3	8.6	8.3	7.0
	3	10.8	10.8	10.6	9.4	8.6	8.6	8.3	7.5
	4	12.2	10.0	10.3	9.4	8.3	8.3	7.5	6.3
	5	9.2	9.7	8.9	7.8	7.2	7.2	7.2	5.8
	6	10.0	10.3	8.3	7.8	7.0	7.8	7.8	7.0
	7	10.3	10.3	9.2	8.3	6.7	7.8	8.9	7.5

TABLE AIIIa-Daily Moisture Content (%) at Four Depths

		May, 1970									June, 1970						
Depth	Site	4	6	8	13	15	19	21	25	29	1	5	8	12	15	18	26
10 cm	1	19	19	18	22	20	19	18	17	14	12	12	12	13	12	20	14
	2	21	21	20	22	23	20	20	19	19	18	14	14	13	16	21	18
	3	20	20	20	19	19	19	19	18	17	15	12	12	12	12	20	14
	4	17	17	17	17	26	23	23	22	22	21	19	17	20	22	26	23
	5	23	23	22	21	20	19	21	18	18	16	13	12	14	13	23	15
	6	73	75	75	75	77	75	75	74	75	76	55	44	41	38	76	76
	7	80	80	80	80	83	81	80	78	75	73	55	48	54	51	59	60
30 cm	1	25	25	24	24	25	23	23	22	21	20	20	19	20	19	30	33
	2	37	32	28	24	23	22	22	21	23	21	19	19	36	38	41	45
	3	19	30	22	30	29	26	25	23	22	21	20	19	24	27	30	31
	4	43	38	43	42	40	30	30	25	23	22	21	22	20	19	43	38
	5	28	28	28	27	28	28	28	27	32	28	25	23	36	31	29	28
	6	54	54	54	55	55	54	53	54	53	53	54	51	53	49	50	51
	7	53	54	52	52	51	52	52	53	53	51	52	52	51	50	51	50
50 cm	1	36	35	33	34	33	27	26	24	23	22	23	20	24	25	48	24
	2	35	36	39	38	39	36	35	34	31	30	27	26	24	20	43	30
	3	28	29	42	37	34	29	27	24	22	21	20	20	22	20	31	24
	4	45	47	44	45	45	43	43	38	30	27	25	24	23	23	45	35
	5	31	32	32	33	33	33	33	32	31	29	27	25	25	24	39	39
	6	53	53	54	54	54	54	54	54	54	54	54	53	53	54	52	55
	7	51	52	51	53	53	53	53	53	54	53	54	53	53	53	53	54
100 cm	1	50	50	50	51	51	54	51	50	44	38	32	29	28	26	52	49
	2	45	50	41	41	40	36	31	29	28	29	23	22	21	20	33	31
	3	41	51	43	43	42	35	33	29	27	26	24	23	22	21	53	54
	4	52	53	53	53	53	53	53	53	53	53	49	43	39	38	53	53
	5	41	49	43	50	50	50	50	49	43	38	36	36	34	52	52	52
	6	54	54	54	54	55	54	54	55	55	55	55	55	55	54	53	54
	7	52	53	53	53	54	54	53	54	54	54	54	54	54	54	54	54

TABLE AIIIb-Daily Moisture Content (%) at Four Depths

		July, 1970						August, 1970							
Depth	Site	3	10	17	20	24	30	4	7	10	14	17	21	24	26
10 cm	1	18	12	12	12	17	22	13	12	13	14	12	12	12	12
	2	20	18	13	13	19	21	18	12	18	18	12	12	12	12
	3	15	12	12	12	13	19	13	12	13	15	12	12	12	12
	4	22	22	18	17	20	31	23	20	25	28	23	18	15	14
	5	25	17	18	18	17	20	19	13	17	18	13	13	12	12
	6	76	78	73	68	71	74	77	79	79	79	80	63	49	43
	7	63	55	48	47	48	53	47	42	66	66	40	35	32	31
30 cm	1	21	19	19	18	21	34	32	29	26	33	19	17	17	17
	2	22	23	23	23	24	28	33	25	42	48	37	21	19	18
	3	23	19	19	18	22	33	23	20	25	30	22	18	17	17
	4	42	34	28	25	28	37	26	23	40	30	24	23	21	21
	5	30	22	20	19	19	22	22	22	21	20	19	18	17	17
	6	50	50	50	50	49	50	50	50	50	50	50	50	50	42
	7	50	49	43	43	45	45	43	41	40	37	36	33	30	28
50 cm	1	23	21	27	23	24	33	23	21	25	22	29	20	18	18
	2	27	26	23	23	17	21	20	19	26	21	19	17	17	17
	3	20	19	19	18	17	16	16	16	16	16	16	16	16	16
	4	31	30	31	27	27	27	30	28	29	27	27	25	25	24
	5	26	24	26	24	23	23	22	22	39	43	34	24	22	21
	6	54	53	53	52	53	53	53	54	54	53	53	53	53	53
	7	53	51	44	43	45	47	44	41	41	39	38	36	33	33
100 cm	1	39	33	32	33	35	38	38	32	35	35	42	32	29	27
	2	28	21	19	19	18	18	17	17	17	17	17	17	17	17
	3	22	19	18	17	17	18	18	18	18	19	19	19	19	19
	4	53	53	42	41	44	52	43	42	54	53	49	42	41	41
	5	42	39	38	37	45	42	51	43	44	40	36	32	32	31
	6	55	52	53	52	52	52	52	53	53	53	52	52	52	52
	7	54	54	54	53	54	54	54	54	54	54	54	49	44	43

TABLE AIIIc-Daily Moisture Content (%) at Four Depths

Depth	Site	September, 1970					October, 1970			
		11	17	22	25	29	1	13	15	21
10 cm	1	12	12	12	12	12	12	13	13	13
	2	12	12	12	12	12	12	16	15	12
	3	12	12	12	12	12	12	15	14	14
	4	17	17	15	22	22	21	25	23	23
	5	13	13	12	12	12	12	13	13	13
	6	29	29	29	29	29	29	33	33	32
	7	42	33	31	31	31	31	40	38	38
30 cm	1	16	16	16	19	20	19	18	18	23
	2	21	19	18	21	23	25	20	20	17
	3	17	16	16	17	21	20	17	17	17
	4	21	20	42	45	37	31	19	38	18
	5	17	17	17	17	17	17	17	17	17
	6	23	21	19	18	18	18	17	17	18
	7	23	22	22	21	21	21	21	21	21
50 cm	1	18	17	17	17	17	17	17	17	17
	2	17	16	17	16	16	16	16	16	16
	3	16	16	16	16	16	16	16	16	16
	4	22	21	23	21	21	21	20	20	20
	5	19	18	18	18	20	20	19	19	18
	6	35	30	30	25	25	25	24	24	24
	7	27	25	25	24	24	25	24	24	24
100 cm	1	28	21	20	20	19	19	19	19	18
	2	17	16	16	16	16	16	16	16	16
	3	16	16	16	16	16	16	16	16	16
	4	36	32	30	29	28	28	26	27	25
	5	26	25	25	25	25	25	25	25	25
	6	52	45	40	40	38	38	37	37	37
	7	36	34	34	34	33	33	33	33	34

TABLE AIIId-Daily Moisture Content (%) at Four Depths

		May, 1971								June, 1971					July, 1971			
Depth	Site	4	10	13	17	19	21	28	31	4	11	18	25	28	2	12	16	22
10 cm	1	19	18	18	17	16	15	13	12	12	23	26	23	23	22	25	20	14
	2	19	21	25	21	18	18	14	12	12	22	22	20	20	20	21	19	13
	3	20	21	18	18	18	17	14	13	12	19	22	19	18	17	23	18	13
	4	23	21	23	22	22	21	18	18	15	31	32	26	26	26	34	27	20
	5	25	21	21	20	23	22	21	18	17	20	31	25	23	24	39	24	18
	6	76	71	71	70	74	63	55	46	42	60	65	80	80	81	81	82	83
	7	79	72	87	86	86	85	82	82	81	83	81	79	75	75	75	77	78
30 cm	1	23	22	20	19	21	20	19	19	18	23	37	24	25	23	41	26	20
	2	28	26	25	24	23	23	20	20	29	24	37	30	25	22	45	31	22
	3	28	27	27	25	25	22	22	22	21	20	20	21	21	21	38	31	23
	4	45	36	33	28	26	24	23	20	19	22	47	42	40	33	38	31	19
	5	25	36	25	25	24	24	21	19	16	28	36	32	34	33	38	31	19
	6	41	45	50	50	50	50	51	53	51	52	51	51	51	52	52	53	54
	7	49	50	53	54	53	54	54	54	55	55	55	55	55	55	55	55	55
50 cm	1	34	30	26	23	23	22	21	20	19	19	25	25	26	24	30	30	25
	2	45	42	38	30	29	28	24	23	22	22	34	32	33	33	51	50	27
	3	36	33	32	30	28	27	22	21	20	19	30	30	26	23	44	41	31
	4	47	48	46	42	42	40	33	32	28	32	52	50	49	45	53	53	47
	5	50	48	44	40	38	36	29	27	25	35	48	46	45	40	48	48	39
	6	53	54	48	48	48	50	51	51	51	52	52	52	53	53	55	55	53
	7	55	55	54	54	55	55	54	54	55	55	54	55	55	55	55	55	55
100 cm	1	52	50	52	51	44	40	33	32	30	28	53	53	53	45	51	52	41
	2	51	52	52	50	52	48	30	28	25	24	32	25	24	23	53	53	33
	3	51	51	51	50	52	51	28	26	23	22	30	26	23	23	50	50	34
	4	52	52	53	53	53	53	53	53	50	53	53	53	54	53	54	54	54
	5	52	53	53	53	53	53	50	46	43	44	53	52	52	53	50	53	53
	6	55	54	53	53	53	53	53	53	53	53	55	55	55	54	54	51	54
	7	55	55	55	56	56	55	56	55	56	55	56	56	54	55	55	55	55

TABLE AIIIe-Daily Moisture Content (%) at Four Depths

		August, 1971							September, 1971				October, 1971			
Depth	Site	4	9	13	16	23	27	30	7	10	17	28	4	12	18	25
10 cm	1	16	13	12	12	12	12	12	12	12	12	16	15	15	15	15
	2	19	12	12	12	12	12	12	12	12	12	16	19	18	19	18
	3	13	12	12	12	12	12	11	12	13	12	12	12	12	12	12
	4	28	18	14	13	12	12	12	13	18	13	22	23	20	19	21
	5	21	13	13	12	12	12	12	13	12	12	14	14	14	13	13
	6	82	81	73	65	43	31	29	29	30	30	38	37	32	31	35
	7	80	82	82	81	68	65	63	59	58	49	52	50	58	58	56
30 cm	1	18	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	2	35	20	17	17	17	17	17	18	17	17	25	28	22	21	20
	3	19	17	17	17	17	17	17	18	18	18	17	17	17	18	18
	4	20	18	17	17	17	17	16	23	20	18	24	28	27	30	30
	5	21	19	17	17	16	16	16	17	18	17	17	17	17	17	17
	6	54	54	55	54	54	53	33	22	20	20	17	27	26	26	25
	7	56	55	55	55	55	53	50	47	44	41	39	34	29	24	20
50 cm	1	21	19	20	18	18	18	17	18	18	17	18	18	18	17	17
	2	24	22	20	19	17	17	17	17	17	17	17	17	17	17	17
	3	25	25	20	18	17	17	16	16	17	16	17	17	16	16	16
	4	44	38	33	32	28	26	25	24	23	22	21	21	21	20	20
	5	30	26	24	23	20	18	18	22	16	19	24	22	21	20	19
	6	53	53	53	53	53	53	54	44	36	27	28	32	32	34	30
	7	56	55	55	55	55	54	52	50	46	43	41	42	42	42	42
100 cm	1	35	33	24	28	23	21	21	20	20	19	19	19	19	19	19
	2	31	27	24	23	20	18	18	23	31	17	17	17	17	17	17
	3	33	25	23	20	19	18	16	19	17	17	17	17	17	17	17
	4	53	54	46	45	42	38	33	33	20	25	24	24	24	24	23
	5	54	54	53	51	41	36	33	28	28	24	24	24	24	24	24
	6	54	54	54	54	54	54	54	54	54	38	39	38	37	40	38
	7	56	55	55	55	55	55	55	55	55	55	55	55	55	55	55

TABLE AIV - Moisture Content (%) at Permanent Wilting Point and Field Capacity

Wilting Point

Site	Depth (cm) 10	30	50	100
1	4	14	14	14
2	5	15	16	9
3	4	16	14	13
4	7	16	17	15
5	6	14	16	15
6	22	16	15	16
7	17	11	11	14

Field Capacity

Site	Depth (cm) 10	30	50	100
1	17	23	24	26
2	17	28	27	20
3	17	25	24	23
4	17	26	28	26
5	19	26	30	28
6	37	27	23	26
7	39	20	20	24

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